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Cover
Acacia pendula (Boree) woodland north-east of Deniliquin. (See Hay Plain vegetation paper pp. 1–122).
Photographer: Marianne F. Porteners

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The natural vegetation of the Hay Plain:
Booligal–Hay and Deniliquin–Bendigo
1:250 000 maps

Marianne F. Porteners

Abstract

Porteners, Marianne F., (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1993. The natural vegetation of the Hay Plain: Booligal–Hay and Deniliquin–Bendigo 1:250 000 maps. Cunninghamia *3(1): 1–122.* The composition and extent of the present native vegetation, both remnant and modified, covered by the following 1:250 000 map sheets is described and mapped from aerial photography and field traverses: Booligal (33°00'S to 34°00'S, 144°00'E to 145°30'E), Hay (34°00'S to 35°00'S, 144°00'E to 145°30'E) and Deniliquin-Bendigo (35°00'S to the Murray River, 144°00'E to 145°30'E). The Hay Plain is situated in south-western New South Wales and is covered by the South Western Plains botanical subdivision. The term Hay Plain is used to refer to that area of the riverine plain covered by these maps. In its wider context it refers to the whole of the riverine plain, comprising the extensive alluvial deposits of the Murray River and its major tributaries, the Murrumbidgee and Lachlan Rivers. The characteristic landscape is an alluvial plain with a westerly to northerly transition to aeolian landforms. Twenty-one vegetation communities occurring within the mapped area are described. These include saltbush (*Atriplex* spp.) and bluebush (*Maireana* spp.) shrublands, perennial grasslands, woodlands of *Callitris* and Belah–Rosewood (*Casuarina pauper* and *Alectryon oleifolius*), riparian forest and mallee communities. Few undisturbed areas of natural vegetation remain due to over 150 years of extensive land use. The poor conservation status of many of the communities is discussed.

Introduction

'It is impossible for me to describe the kind of country we were now traversing, or the dreariness of the view it presented. The plains were still open to the horizon, but here and there a stunted gum-tree, or a gloomy cypress, seemed placed by nature as mourners over the surrounding desolation' (Charles Sturt 1833).

The Hay Plain in south-western New South Wales is an expansive alluvial plain dominated by chenopod shrublands and bisected by a network of wooded rivers and creeks. Known also as the saltbush plain it is considered by many to be a bleak and desolate place but to others it conjures up romantic images of Cobb and Co. coaches transporting mail and goods to lonely outposts; the solitary pub on the One Tree Plain and early settlers trying to make a living from marginal, inhospitable land. The landscape has been extensively modified over the past 150 years by European settlement. The saltbush plains have been heavily stocked with sheep and to a lesser extent with cattle and the more arable lands adjacent to the rivers have been cleared for cropping. Forests and woodlands of *Eucalyptus camaldulensis* and *Eucalyptus largiflorens* still line the rivers and creeks and cover extensive floodplain areas. Relatively small areas remain of once-extensive *Callitris glaucophylla* and *Acacia pendula* woodlands, which were logged for building materials and fodder. Widespread dieback of *Atriplex vesicaria* has considerably reduced this once-dominant vegetation community. Little of the vegetation is represented in any conservation zone and few undisturbed areas exist today.

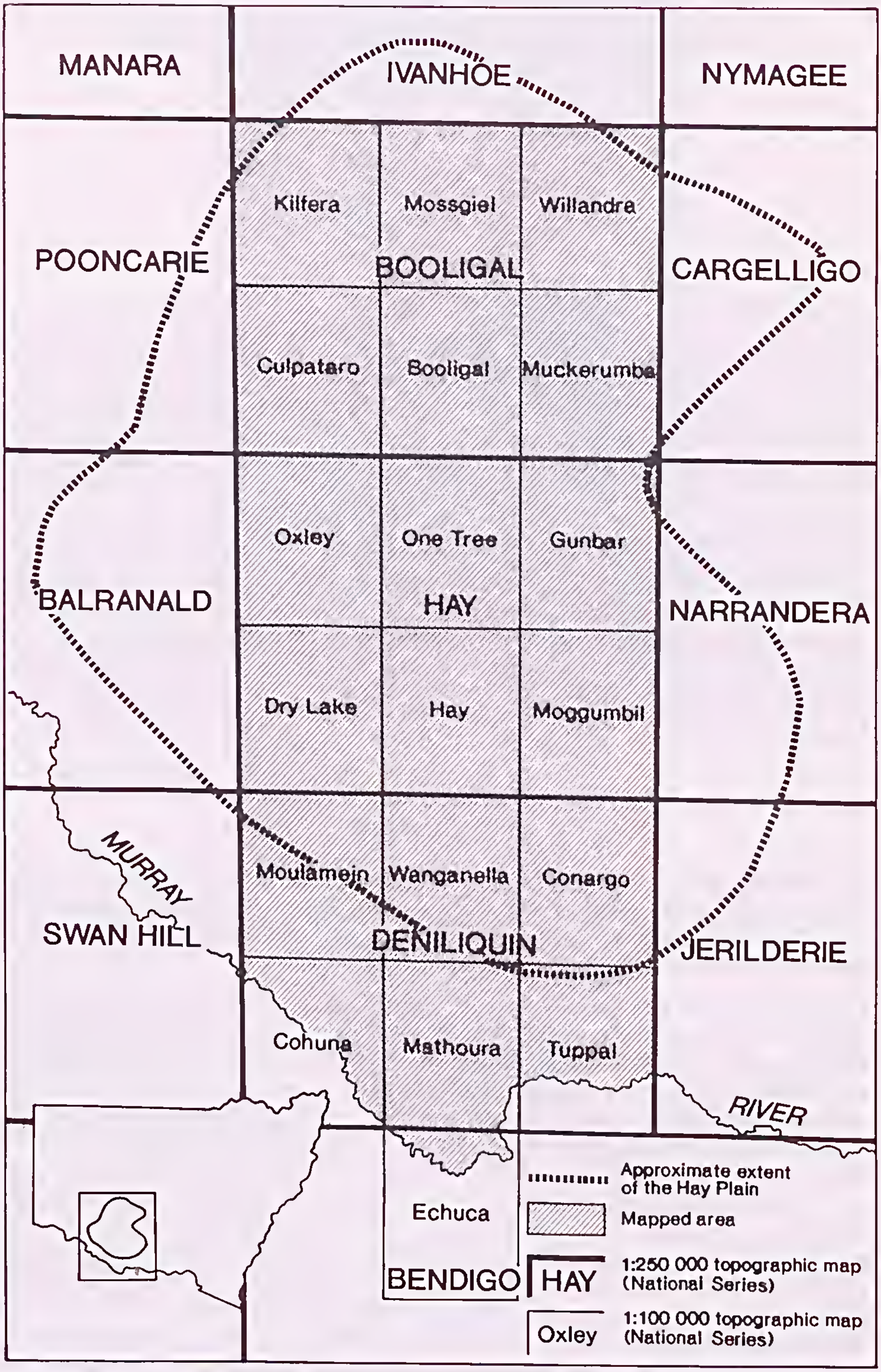

Figure 1. Locality map showing the extent of the Hay Plain in south-western New South Wales, and the associated map sheets.

Location

The Hay Plain in south-western New South Wales is covered by the Australian 1:250 000 Topographic Survey sheets Booligal, Hay and Deniliquin (SI 55–5, SI 55–9, SI 55–13) and a portion of the Bendigo Joint Operations Graphic (SJ 55–1) (Fig. 1). The term riverine plain has also been used to describe the larger area covering the whole alluvial plain across which the Murray and Murrumbidgee Rivers flow westward from the eastern highlands (Beadle 1948, Moore 1953, Butler 1950). Portions of the Hay Plain occur on the Cargelligo, Narrandera, Jerilderie and Balranald–Swan Hill 1:250 000 maps and many of the vegetation communities identified in the current survey extend to these areas. The Lowbidgee region, a low, very flat and relatively recent floodplain where the surface relief of palaeochannels has been obscured by more recent deposition, occurs further west between Maude and Balranald.

The total area mapped is 4 392 200 ha or almost 4.5 million ha. Each complete 1:250 000 map covers an area of 138 X 110 km (or 1 524 900 ha) and the New South Wales portion of the Deniliquin–Bendigo map covers an area of 1 342 400 ha. Much of the mapped area falls within the Central Division of New South Wales, where the land is under freehold tenure. North of the Lachlan River in the Western Division, most of the land is held under perpetual grazing lease with some areas of freehold country.

The major townships are Hay and Deniliquin with populations of 3000 and 7250 respectively (Fig. 2). Smaller towns from north to south include Mossgiel, Booligal, Oxley, Carrathool, Maude, Moulamein, Wanganella, Conargo, Barham, Mathoura and Moama. Just off the map but used for reference are Hillston to the east of the Booligal map and Ivanhoe to the north. Most of the mapped area falls under the Carrathool, Hay, Windouran, Conargo and Murray Shires with small portions in the Central Darling, Balranald, Murrumbidgee and Wakool Shires. The Sturt and Cobb Highways traverse the mapped area from east to west and north to south respectively. The Mid-western Highway enters the Hay map in the north-east from West Wyalong while the Riverina Highway similarly connects Deniliquin to towns further east. The now unused Junee–Hay railway line enters the map area from the east, terminating at Hay and a portion of the Sydney–Broken Hill line crosses in the far north-east of the Booligal map sheet.

The eastern boundary of the mapped area is at longitude 145°30'E which runs east of Roto, Gunbar, Carrathool, Four Corners and Conargo and west of Hillston and Tocumwal. The western boundary is at longitude 144°00'E which runs west of Ivanhoe, Oxley, Moulamein and Barham. The northern boundary runs almost parallel with the Sydney to Broken Hill railway line but south of Ivanhoe and Conoble siding, with Trida and Roto sidings and Warranary Hill within the mapped area in the east. The Murray River forms the southern boundary with the townships of Barham, Moama and Echuca (Vic.) on its banks.

The dominant features of the mapped area are the major rivers. The Murrumbidgee River runs east-west through the Hay map area, with the Lachlan River joining in the west at the Great Cumbung Swamp. The Murray River in the south defines the state border between New South Wales and Victoria at its southern bank. Its anabranch, the Edward River, traverses the Deniliquin map and rejoins the Murray to the west of the mapped area near Kyalite. Willandra Creek crosses the Booligal map in the north, terminating in the depressions of the Willandra Lakes system further west.

Climate

The general climate of the Hay Plain is semi-arid, with very hot summers, mild winters and a winter-dominant rainfall (Edwards 1979). The diurnal contrast is one of

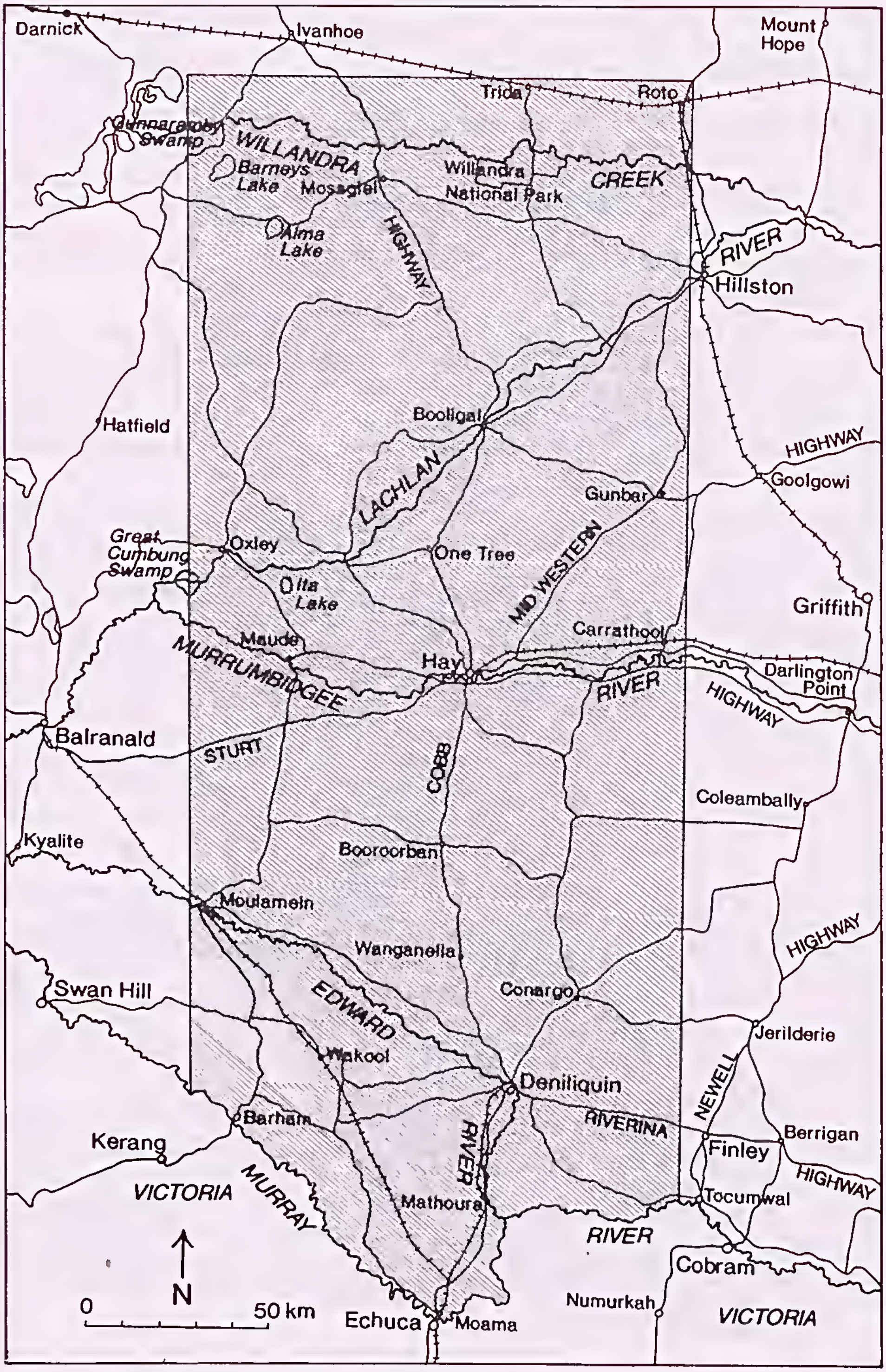

Figure 2. Major natural features and communications of the mapped area (Booligal–Hay and Deniliquin–Bendigo map areas shaded).

hot days and cool nights in summer and warm days and cold nights in winter. Dry years are common and often consecutive, resulting in prolonged periods of drought, often lasting several years. Topography does not exert a strong influence on the climate of the region, except for local restrictions and modifications of air flow. Most of the climatic variation is due to the wide longitudinal spread of the region (Bureau of Meteorology 1955). Climatic averages for Deniliquin, Hay and Ivanhoe (temperature and rainfall data) and Booligal and Mossgiel (rainfall data only) are given in Table 1.

The hottest month is January when average daily temperatures range from 17.2–33.0°C at Hay while the lowest temperatures normally occur in July, with an average range of 3.6–14.8°C (Bureau of Meteorology 1988). Ivanhoe, at the far northern edge of the Plain experiences slightly hotter summer and cooler winter temperatures while temperatures in Deniliquin, in far south of the mapped area are slightly lower in summer and winter.

In south-western New South Wales, annual rainfall decreases from east to west with a predominantly winter dominance that increases towards the south. Further north, the rainfall decreases and is more evenly spread throughout the year. Correspondingly, evaporation increases from east to west. Summer rainfall is generally from localised thunderstorms, while the more reliable winter rains result from cold fronts associated with the passage of depressions across the southern ocean (Rhodes 1990). The average annual rainfall decreases from about 400 mm at Deniliquin to 300 mm at Ivanhoe in the far north-west. The peak winter rainfall for the Hay district is 240–360 mm (Edwards 1979).

Rainfall is most reliable during the months of July and August and the most variable during the January to March quarter. Rainfall variability increases in the north and west of the area. Evaporation is at its highest during the period of November to February. The June to September period is generally the most favourable for plant growth due to the higher winter rainfalls (Rhodes 1990). Dry periods are not unusual and approximately 29 drought years were experienced in western New South Wales between 1900 and 1986 (Dalton 1988).

Geology

The Hay Plain consists of two broad geological types: the fluvial plains comprising alluvial and lacustrine deposits of gravel, sand, silt and clay, and the aeolian landscape of flat to gently undulating plains and dunes of red clayey sands and loams (Semple 1990) (Fig. 3). Bedrock hills of Palaeozoic sediments mark the edge of the Murray Basin in the extreme north-east of the mapped area at Warranary Hill and on the Manfred Range in the central north (Norris & Thomas 1991). Low ranges and rocky outcrops to the east represent the boundary between outcropping Palaeozoic bedrock and the Tertiary/Quaternary alluvial plains (Norris & Thomas 1991). To the west the landscape becomes aeolian in character, marking the transition from riverine sediment sources in the east to marine and littoral sources from the west (Mabbutt 1980).

The Hay Plain lies within the Murray Basin which was formed during the Tertiary Period about 60 million years ago (Semple & Eldridge 1989). Active sedimentation followed by fluvial deposition by prior streams gave the present landscape its form (Pels 1969a). In the late Tertiary the western part of the Basin was covered by sea and extensive deposits of marine sands were laid down. This area, known as the Murravian Gulf, extended east to about Hatfield and north to half-way between Mildura and Menindee. The gulf regressed during the Pliocene and carbonates and clays were deposited in the early Quaternary when the western part of the region was again

Table 1. Climatic averages for Deniliquin, Hay and Ivanhoe (temperature and rainfall data) (Bureau of Meteorology 1988) and Booligal and Mossgiel (rainfall data only) (National Climate Centre 1992).

	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Deniliquin (22 years of temperature record and 126 years of rainfall record)												
Daily max. temp. (ºC)	31.5	31.8	27.8	22.8	18.1	14.8	13.9	16.0	18.7	22.7	26.4	29.4
Daily min. temp. (ºC)	15.9	16.7	13.7	10.0	7.2	4.2	3.3	4.9	6.6	9.3	11.8	14.1
Rainfall (mm)												
Mean	29	28	33	32	40	41	35	37	38	40	28	28
Median	16	15	21	23	34	36	31	35	33	33	20	20
Mean no. raindays	4	3	4	5	7	9	9	9	8	7	5	4
Hay (29 years of temperature record and 106 years of rainfall record)												
Daily max.temp. (ºC)	33.0	32.6	29.0	24.0	18.8	15.9	14.8	17.0	20.2	24.2	28.2	31.0
Daily min. temp. (ºC)	17.2	17.2	14.6	10.6	7.4	4.6	3.6	5.0	6.9	10.1	12.8	15.3
Rainfall (mm)												
Mean	27	29	30	30	35	36	29	32	31	36	25	25
Median	13	16	21	22	30	32	25	28	27	28	17	15
Mean no. raindays	3	3	4	5	6	8	8	8	6	6	4	4

Booligal (rainfall statistics for the period 1891 to 1991 using all available data)

Rainfall (mm)												
Mean	26	22	32	26	34	32	27	28	25	31	24	24
Median	12	9	17	17	27	27	25	26	19	22	17	15
Mean no. raindays	3	3	3	3	5	6	7	6	5	5	4	3

Mossgiel (rainfall statistics for the period 1894 to 1978 using all available data)

Rainfall (mm)												
Mean	26	26	28	19	28	29	23	25	23	29	22	26
Median	11	11	14	12	20	21	16	21	16	19	16	14
Mean no. raindays	3	3	3	3	4	5	5	5	4	4	3	3

Ivanhoe (25 years of temperature record and 101 years of rainfall record)

Daily max. temp. (°C)	34.0	34.0	30.6	25.6	20.1	16.9	16.2	18.6	21.8	26.2	29.9	32.8
Daily min. temp. (°C)	17.9	18.2	15.0	10.5	6.9	3.9	3.2	5.0	7.2	11.1	13.8	16.4
Rainfall (mm)												
Mean	28	26	28	20	27	26	22	24	21	28	23	26
Median	10	11	16	11	21	23	17	20	16	20	13	13
Mean no. raindays	3	3	3	3	5	6	5	5	5	5	3	3

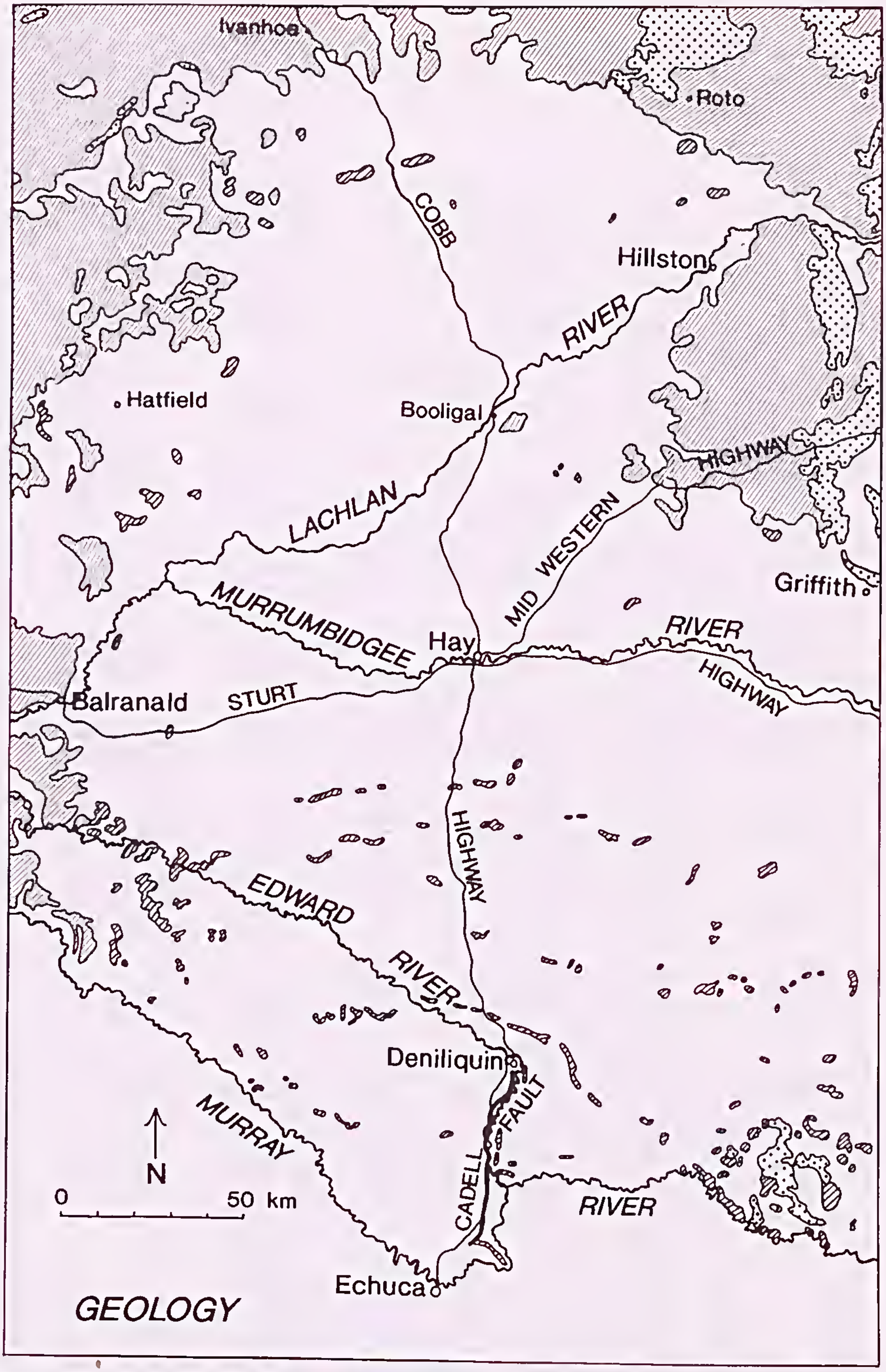

Figure 3. The geology of the mapped area. White unhatched areas indicate flat, alluvial and lacustrine deposits of clay, silt, sand and gravel. Hatched areas are largely aeolian, flat to gently undulating plains and dunes of red and red-brown clayey sands and loams. Spotted areas are sandstone-conglomerate sediments (slate and granite in the far south-east). Based on Goldbery and West (1968) and Offenberg (1969).

inundated by the freshwater Lake Bungunnia (Semple & Eldridge 1989, Bowler 1980).

Alluvial deposits were laid down in the eastern part of the Basin from the late Tertiary until recent times. The entire plain consists of interbedded sand and clay which was deposited by prior streams from the Palaeozoic eastern highlands. Butler (1958) proposes three main intervals of deposition, between which there were periods when the streams entrenched their beds and no deposition occurred. These streams were independent of the present day rivers and are still visible on the plain surface today (Schumm 1968). The present surface of the Plain is therefore a relict landform representing the final phase of prior stream deposition. The youngest prior streams are aged at around 36,000 years (Pels 1964b), indicating that their activity ceased in the late Pleistocene.

After prior-stream activity ended, the drainage pattern of the plains underwent major changes. Some of the major prior streams acted as drainage lines while present rivers cut across and in part along them. This coincided with a period of increased aridity (Hawkins & Walker 1956). The most recent fluvial deposit forms the floodplain of the Murrumbidgee River and filled the ancestral Murrumbidgee River cutting (Butler 1950). The interconnected basins of the Willandra Lakes System, west of the mapped area, were fed by the Willandra Billabong Creek, a distributary stream which left the Lachlan River near Hillston. This creek ceased to flow some 15 000 years ago and the lakes dried out. Willandra Creek, presently situated in the far north of the Hay Plain, formerly flowed into the Murray River but its flow was taken over by the Lachlan River. Under the present drier climate it terminates in a series of dry lakes, saltpans and depressions, the modern-day terminus being Gunnaramby Swamp just west of the mapped area.

Tectonic movements may have been responsible for the change from prior stream courses to present-day river courses. A striking feature of the southern Hay Plain is the deflection of the Murray River and the displacement of prior streams, by the Cadell Fault (Harris 1939). The Fault, visible as an uplifting of the floodplain between Echuca and Deniliquin, stopped the usual flow of the Murray River from Tocumwal westward to Barham. The river formed two new outlets, the present Murray River to the south through Echuca and the present Edward River to the north through Deniliquin. The uplift is only 20 m high and is straddled by the Cobb Highway north of Echuca. This relatively recent tectonic event is estimated to have occurred about 20 000 years ago (Bowler 1967).

Geomorphology

The geomorphology of the Hay Plain is essentially fluvial in character, with minor aeolian and lacustrine elements (Fig. 4). Stream deposition has given the Plain its form, with erosion to a lesser extent. It is basically an inland floodplain with some low relief, dissected by rivers, creeks and ancestral and prior streams. Butler *et al.* (1973) defined it as a series of gently sloping alluvial fans and the floodplains onto which they merge. Isolated low rises to less than 100 m elevation occur throughout the area. Aeolian forces have shaped the landscape further north and west where sandplains, dunefields and low rocky outcrops arise.

Plains

Fluvial elements have produced plains with different surface characteristics. The Hay Plain may be broadly divided into three geomorphological types based on the major floodplains: the southernmost, uplifted and heavily channelled plains of the Murray which receive the highest rainfall, the highly scalded plains of the Murrumbidgee, and the broad Lachlan River plain which receives the lowest rainfall and has many

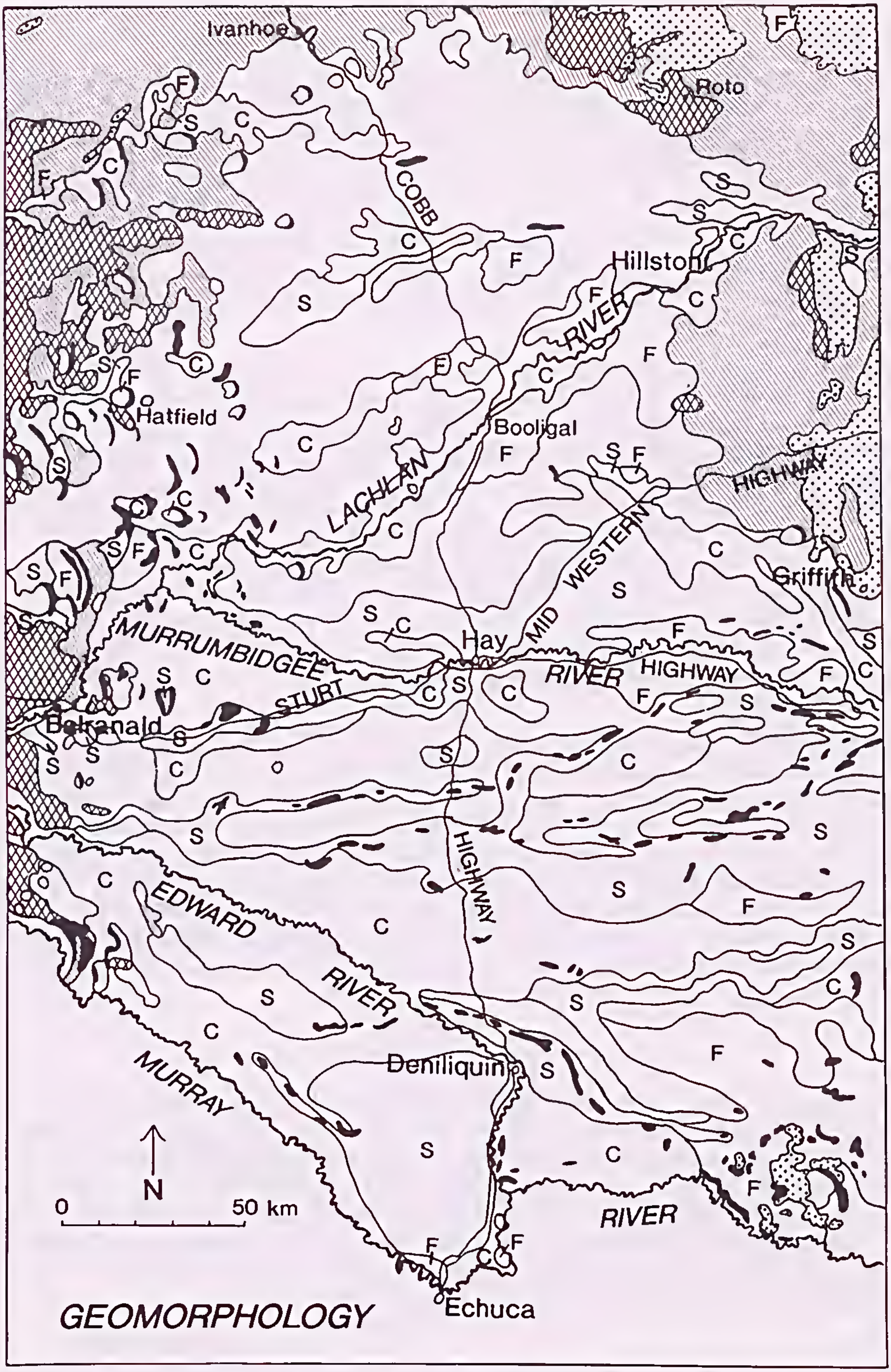

Figure 4. Geomorphology and landform features of the mapped area, based on Butler *et al.* (1973). Spotted areas are Palaeozoic ranges, hills and associated slopes. Double-hatched areas are dunefields. Lightly-hatched areas are aeolian plains. Black areas show source-bordering dunes, lunettes and lunette remnants. Unhatched areas indicate plains: unlabelled — plains with depressions, or lakes; C — channelled plains; S — scalded plains; F — featureless plains.

low depressions (Morgan & Terrey 1992). The Plain surface consists predominantly of clays that were deposited from prior streams when water was isolated beyond the levees on extensive floodplains (Pels 1969a). Consequent fluvial forces have produced alluvial plains with depressions, channels or little feature.

Present rivers

River channels such as those of the Murrumbidgee and Lachlan are deep and narrow, with steep clay banks and carry a large proportion of their sediment load in suspension. These present rivers are not old but are new eroding channels, cutting through alluvial deposits bought down by prior streams (Butler 1950). They form a branching system which eventually feeds into the Murray River (Butler *et al.* 1973). Stream flow is variable and during dry periods many of the smaller creeks dry up completely. Even major creeks and rivers, or portions of them, have been known to dry up during prolonged drought. Most rivers or creeks on the Plain terminate in lakes, saltpans or dunefields but several of them, such as the Edward and Wakool Rivers, branch off the main stream and rejoin again, forming an anabranch. Often the stream breaks up into a complex system of smaller creeks and channels as seen in the drainage system of the Lachlan River within the mapped area.

Prior streams and ancestral rivers

Two types of ancient stream systems have been identified on the basis of their form and age (Butler 1950). Prior streams are indicated by low, winding, sandy rises on the clay floodplain; these are elevated remnants of the old stream beds. Associated with these rises of coarse alluvium may be low, fixed sand dunes, described as source-bordering and formed by the redistribution of the coarse stream bed deposits derived from the old levees. Ancestral rivers are a younger system of remnant channels with the beds of sediment below the level of the adjacent plain. These often carry water during floods.

While current and ancestral rivers carry much of their sediment in suspension, prior streams were of a bedload type, depositing their sediments (Schumm 1968). The current bed level of prior streams is higher than the adjacent floodplain due to their once-depositional nature. Prior streams near Griffith have been aged at 36 000 years (Pels 1964b) and ancestral rivers between 30 600 and 4 200 years (Pels 1969b). Pels (1964a) also found that prior streams pre-dated the Cadell Fault and ancestral streams mostly post-dated it. Prior stream remnants today carry a different vegetation from the surrounding plain and other stream types.

Lakes

The dry basins of shallow lakes are a common geomorphological feature of the Hay Plain. Permanently filled natural lakes are less common, most being artificially-filled reservoirs or evaporation basins for irrigation or drainage. The lakes are generally circular, elliptical or kidney-shaped in outline with the long axis aligned north–south. The beds of dry lakes tend to have the characteristics of the adjacent plain and a dune ridge or lunette of sandy sediment overlying clay may be present along the eastern edge.

Aeolian landforms

Aeolian elements are not common on the Hay Plain and take the form of isolated low dunes, lake lunettes formed by the accumulation of sandy material and sandplains overlying deeper clay soils and which are often scalded. Sand dunes vary in height from 3–15 m and most are source-bordering, usually associated with prior streams and to a lesser extent with ancestral rivers (Pels 1964a, Bowler & Harford 1966).

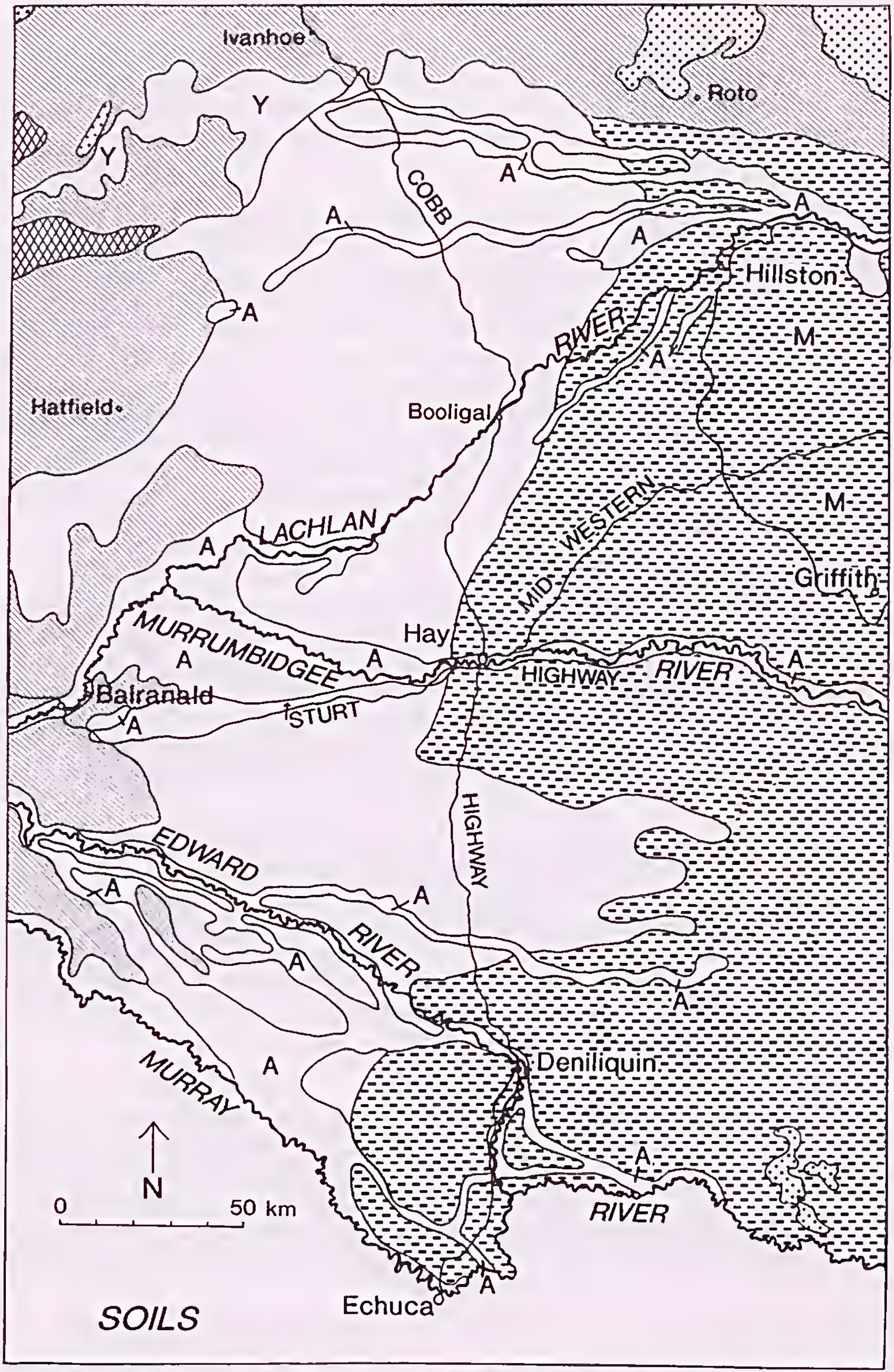

Figure 5. The distribution of soil types within the mapped area, based on Eldridge (1990). Unhatched areas indicate clays: unlabelled — deep, grey, cracking clays; Y — deep, yellow, cracking clays; A — ancestral streams and floodplain complex. Dashed areas are the red-brown earths group of hard, duplex soils (M — massive red earths in the east between Hillston and Griffith). Lightly-hatched areas are desert loams (calcareous earths). Double-hatched areas indicate deep, loose sands. Spotted areas are lithosols of shallow sandy soils.

Lunettes are generally crescent-shaped, following the curvature of the lake on its eastern edge (Butler *et al.* 1973). Scalding is the result of the removal of surface soil by wind, leaving bare areas of harder B-horizon soils which can vary from patches a few meters in diameter to vast areas of several square kilometres. Unvegetated, scalded areas are common on the Hay Plain.

Other aeolian sediments apart from the sand dunes and scalds occur on the Plain. Clay sheets, termed 'parna' by Butler (1956), occur over much of the Plain or interbedded with fluviatile sediments. They consist of redistributed materials derived mainly from prior stream levees and beds and are apparently more common on the eastern edge of the Hay Plain as a sheet 1–2 m thick (Schumm 1968). The source of the parna was to the west and is evidence of a period of severe aridity separating the last two phases of prior stream activity (Butler 1950).

Soils

The predominant soils of the Hay Plain are deep, self-mulching, cracking clays (Fig. 5). consisting of grey, brown and red clays. Hard duplex soils of red-brown earths overlying grey and brown clays are seen in the north-east of the mapped area while desert loams of crusty red duplex soils are common further west and north. Isolated sandy rises and lunettes occur throughout, with deeper sandplains to low dunefields occurring at the north-west to north-east edges of the mapped area. Prior streams of coarse sand to gravel are common in the south-eastern sector of the mapped area.

Soil fertility is generally low in arid zone soils which are deficient in nitrogen and phosphorus (Leigh & Noble 1972). Soluble salts and pH increase with depth throughout the soil profile while organic matter and nitrogen levels decrease (Dalton 1988). There is a great amount of organic matter input from annual and short-lived perennial species when they die off over summer, while long-lived perennial species such as *Atriplex vesicaria* deposit organic matter into the soil year-round (Rixon 1970). Little nitrogen input is available to plants from sheep faecal pellets due to their slow and inefficient breakdown in the dry soils (Rixon 1970). Soil salinity and surface calcareousness increases across the Plain corresponding with increasing aridity (Butler *et al.* 1973).

The following soil categories are based on Eldridge (1990) while those in brackets are from Abraham (1987):

Grey, brown and red clays (Coarsely cracking clays)

As the most extensive group of soils found in the area, the clays occur on the beds and floodplains of the major river and creek systems, on low-lying areas of the plain and in lake beds. The grey clays occur on lower-lying areas while the brown and red clays are generally found on higher, better drained sites (Eldridge 1990). Gilgai development is often seen in clays occupying lower levels (Dalton 1988). Deep grey clays are most common in the north and west of the Hay Plain while deep yellow-grey clays are associated with the Willandra Lakes System, ancestral streams, the Lowbidgee floodplain and the Darling River. Clay soils are less susceptible to erosion than sandy or loamy soils due to their compact nature.

Red-brown earths (Scalded red texture-contrast soils)

These soils occur over an extensive area of the eastern and southern riverine plain, grading into areas of grey and brown clays further west. They are moderately fertile texture-contrast soils with hard setting topsoils prone to structural breakdown (Abraham 1987). They occur south-west to north-east of Deniliquin and north-east of Hay, on elevated plains and prior-stream levees. Wind erosion is prevalent on this soil type and scalds are common, especially on the levees of prior streams. Water infiltration and holding capacities of these soils are generally high (Eldridge 1990).

Desert loams (Calcareous earths)

These soil types are usually found in the transition zone between the riverine and aeolian plains. They are characterised by a brown sandy loam to loam surface with a brittle crust, overlaying red to red-brown clay subsoils with an accumulation of calcium carbonate (Eldridge 1990). These soils are also susceptible to windsheeting and scalding.

Sands

Many isolated and semi-continuous sandhills occur throughout the mapped area. Earthy sands are found on dunes, lunettes, sandy rises and in sandy swales. Sandplains and low dunefields with deeper sands supporting mallee mark the start of the aeolian landscape in the north-west to north-east. The coarse channel sediments of prior streams comprise gravelly sand, clayey sand or light sandy clay loam. The sediments of prior stream levees grade from sandy clay loam to fine sandy clay (see red-brown earths) textures.

Palaeovegetation

The pollen floras from inland Australia are mostly of lower Tertiary age and indicate the existence of closed forests, with abundant *Nothofagus* in pollen assemblages (Martin 1981). The arid zone flora of Australia began to develop during the Miocene, approximately 15 million years ago (Barlow 1981). There is little evidence of the development of the modern *Eucalyptus* flora or of the arid flora because of the bias of pollen preservation towards permanently wet sites (Martin 1981). It appears that it was too dry for abundant pollen preservation to the west of Narrandera. In the Murray Basin during the Eocene, about 45 million years ago, Martin (1978) found that *Nothofagus* pollen types were most abundant in the fossil record, followed by Casuarinaceae, gymnosperm, Proteaceae and Myrtaceae.

Geographic variation appears to have occurred in Tertiary floras and vegetation (Martin 1981). The disappearance of *Nothofagus* and its associated flora during the Mid-Miocene about 15 million years ago coincides with developing aridity. A gradient in the Pliocene pollen assemblages (about 5 million years before present) appears to parallel the east-west climatic gradient in western New South Wales. The change to open woodlands and forests and savannah coincides with the onset of a marked seasonal dry period.

Vegetation

Descriptions of the Hay Plain are almost synonymous with the adage 'saltbush plains'. *Atriplex vesicaria* and *Maireana aphylla*, with *Atriplex nummularia* to a far lesser extent, are the principal species of these shrublands that dominate the landscape. Perennial saltbush shrublands extend discontinuously from the riverine plain in New South Wales to large areas of South Australia and to southern Western Australia (Dalton 1988). A network of current and ancestral rivers and creeks supports *Eucalyptus camaldulensis* and *Eucalyptus largiflorens* woodlands while scattered low sandy rises and prior streams carry *Callitris*-dominated remnants. The perennial grasslands in the east of the Plain are indicative of greater land use in this higher rainfall area. The change from alluvial to aeolian landscapes in the north-west is marked by sandplains carrying *Casuarina pauper* and *Alectryon oleifolius* open woodlands, *Maireana pyramidata* and *Maireana sedifolia* shrublands, and mallee communities.

The vegetation of the Hay Plain was mapped by Beadle (1948) as an essentially homogeneous area of *Atriplex vesicaria*. While *Atriplex vesicaria* shrubland dominates the Plain today, much of it has been modified by intensive grazing and dieback events. The most widespread change in recent years to the low shrublands has been the replacement of *Atriplex vesicaria* by *Maireana aphylla*. The composition of these and other chenopod shrublands has been further modified with the establishment of *Sclerolaena* species, annual *Atriplex*, *Nitraria billardierei* and other species indicative of disturbance.

Aboriginal History

The Aboriginal people have occupied the country for at least 30 000 years, with the earliest known evidence coming from Lake Mungo east of the Hay Plain (Flood 1990). Several large Aboriginal tribes lived around the rivers and on the Hay Plain itself. The Wiradjeri tribes lived on the plains east of the Darling (Mullins *et al*. 1982). The Nari-Nari, Mudi-Mudi and Gurendji occupied areas of the Murrumbidgee River between Hay and the Great Cumbung Swamp while the Yida-Yida lived near the Lachlan River north-west of Hay. Tribes along the Murray River from east to west included the Banggarang, Yota-Yota, Baraba-Baraba, Wamba-Wamba, Wadi-Wadi and Dadi-Dadi (NSW Department of Lands 1987). Charles Sturt's encounters with the Aboriginal people along the Murrumbidgee River were published in 1833, in the accounts of his expeditions.

Many plant species were used by the Aboriginal people of the area. They yielded edible tubers, fruits and seeds, wood, fibre and other materials. The ripe orange fruits of *Pittosporum phylliraeoides* were eaten and the sticky red seeds pounded into a flour. The berries of the Emu Bush (*Eremophila longifolia*), and the ripe fruits and oily seeds of the Quandong (*Santalum acuminatum*), were also eaten. The starch-rich spore capsules of *Marsilea drummondii* were a valuable food source for Aborigines, although they preferred other foods and used it more as a standby during dry periods (Mullins *et al*. 1982). The starchy pith of *Typha* species (bulrushes) was eaten as cakes and the fibre used for nets and bags. Grass seeds were gathered by the women and used for flour (Beveridge 1883).

The Aboriginal people also depended on the rivers, which would be full after winter rains, yielding fish, yabbies (freshwater crayfish), mussels, tortoises and water-fowl. Fish was the principal component of the diet for eight months in the year (Beveridge 1883). Away from the rivers, out on the plains, survival depended on water-finding skills. Soaks and wells were dug to tap underground seepage, water from rare rain showers was collected, and often the roots of *Hakea* and mallee species were tapped for their stored water. Active changes were made to the environment, with the burning of shrublands to flush out small animals and other game. Rock fishtrap complexes were also built and creeks were dammed. Temporary dwellings called mia mias were built on the open plains from mulga wood interlaced with sods of grass, although this was probably more common further west (Mullins *et al*. 1982, Beveridge 1883).

A number of Aboriginal sites have been recorded for the Hay Plain, including campsites, middens and ceremonial sites. An Aboriginal art site exists in the Booligal area and canoe trees are occasionally seen in the riverine forests. Small amounts of land are held by Aboriginal Land Councils and other bodies at sites in the area, including freehold land at Balranald and a leasehold site at Moonacullah just north of Deniliquin (New South Wales Department of Lands 1987).

European exploration and settlement

The first attempted traverse of the Hay Plain was by John Oxley in 1817. His party crossed the Cocoparra Ranges, travelled to Rankin Springs and down the Lachlan River until they were stopped by the much-branching *Muehlenbeckia florulenta* swamps downstream of Booligal. In 1836 Thomas Mitchell succeeded in following the Lachlan to its junction with the Murrumbidgee River. Charles Sturt explored the Murrumbidgee and Lower Murray Rivers during two expeditions between 1828 and 1831 (Sturt 1833). He made many references to the Hay Plain noting that '*... nothing could exceed the apparent barrenness of these plains, or the cheerlessness of the landscape.*' On the vegetation he remarked '*... we journeyed mostly over extensive and barren plains ... covered with the salsolaceous class of plants, so common in the interior ... and were as even as a bowling green ... We passed a very large plain in the course of the day, which was bounded by forests of box, cypress, and the acacia pendula, of red sandy soil and parched appearance.*' (Sturt 1833).

Between 1835 and 1839, pastoral runs averaging 20 000 to 40 000 ha were taken up as far west as Hay (Semple 1990). They were mainly stocked with cattle and were situated along the Murray and Murrumbidgee Rivers and the Yanko and Billabong Creeks. By 1845 land had been taken up as far west as the Murray–Murrumbidgee junction with stations averaging 80 000 ha. Some of the older stations still existing today include 'Uardry' (1840), 'Deniliquin' (1842), 'Eli Elwah' (1844) and 'Nap Nap' (1845). With the discovery of gold in Victoria in the 1850s, the Hay Plain became a fattening ground for travelling stock heading for the goldfields and this coincided with the development of stock routes linking the major towns on the Plain (Dalton 1988). Sheep grazing became the dominant pastoral activity during the 1860s, with riverboats emerging as a major form of transport. Hundreds of pastoral properties and holdings now exist on the Hay Plain, with the townships of Hay and Deniliquin as major centres.

Land Use

Sheep grazing for wool production is the main land use in dryland areas such as the Hay Plain (Semple 1990). In 1893-1895 stocking rates were about 2.5 sheep per hectare in the Deniliquin area, about the same as present stocking rates on irrigated, improved pasture. By the turn of the century, the extent of land degradation in the Western Division due to the combined effects of overstocking, droughts and rabbits was severe. This led to the appointment of a Royal Commission, which resulted in the passing of the Western Lands Act of 1901, previously administered by the Western Lands Commission (Grant 1989) and now administered by the New South Wales Department of Conservation and Land Management, Western Division. A more current sheep stocking rate on the saltbush plains is 0.4–0.8 sheep per hectare (Leigh & Noble 1972). The grasslands and saltbush plains are considered the most productive of the semi-arid grazing lands of southern Australia and the mallee lands the least productive (Semple & Eldridge 1989), although mallee communities are considered to have a high biological diversity (Calder 1990).

Cropping commenced on a small scale in the 1880s, south of Deniliquin. Most of this was dryland cropping with some irrigation at Mildura. The areas south of Hillston and Balranald were first cleared for cropping in the early 1900s. The general area of crops increased considerably after the First World War but dropped off during the Depression of the late 1920s to early 1930s. Large, state-sponsored irrigation schemes were implemented before and immediately following the Second World War. The state-sponsored Murrumbidgee Irrigation Area has been described as the richest tract of agricultural country in Australia. Other irrigation programs on the riverine plain include the Hay, Colleambally and Tullakool Irrigation Areas. Many smaller holdings are part of private irrigation schemes. The main rural products are wool, beef, mutton, horticultural products, wine, rice, winter cereals and River Red Gum timber with increasing wheat production in dryland areas (Semple 1990). Clearing and cultivation on Western Division leasehold land are controlled by the Department of Conservation and Land Management, Western Division.

Prior streams are exploited as a source of sand and gravel for road building and numerous small pits and quarries have been opened in the major stream beds across the Plain. In recent years, existing sandhills on the Hay Plain have been developed for potato growing, although wind erosion is a big problem in these areas (Semple & Eldridge 1989). Soil loss due to land use has been high in certain pastoral situations and it is believed that much of the damage was done in the first 20 to 40 years of European settlement (Denney 1992). Rabbits were introduced into the area in the 1870s and rapidly multiplied, with almost a million killed on 'Tupra' station in 1890 (Semple 1990). They have been the cause of widespread land degradation on the Hay Plain and elsewhere in western New South Wales.

Previous botanical surveys

General surveys for western New South Wales

As research officer and botanist for the Soil Conservation Service at Condobolin, Noel Beadle comprehensively mapped the vegetation of western New South Wales in the late 1940s. He identified 35 plant associations and 'associes' for western New South Wales and produced a vegetation map at approximately 1:1 000 000 scale (Beadle 1948).

Stannard (1958 & 1963) conducted erosion surveys for the south-west Cobar peneplain and the central east-Darling region and included vegetation and soil maps for each of these areas. The vegetation classification was based on the work of Beadle (1948). Parts of these maps coincide with the far north-east and far north-west corners of the current survey area respectively.

The Anabranch–Mildura (Fox 1991) and Balranald–Swan Hill (Scott 1992) 1:250 000 vegetation maps have been published as part of the western component of a vegetation mapping program at the Royal Botanic Gardens in Sydney. A 1:1 000 000 vegetation map of north-western New South Wales has also been prepared (Pickard & Norris, in press).

Technical manuals, graziers' guides and literature surveys covering a wide range of vegetation types and species have been compiled by the New South Wales Soil Conservation Service (now incorporated in the Department of Conservation and Land Management); these cover the Hay Plain and western New South Wales generally.

Land Systems Maps (Walker 1991) have been published for the whole of the Western Division, including the Booligal–Hay 1:250 000 area. These maps describe the recurring patterns of vegetation, soils and topography. Various species lists have been compiled for Soil Conservation Service experimental exclosures established between 1950 and 1952 and for other study sites across the Plain, by Cunningham and Milthorpe (1981) and Semple (1986).

Surveys covering the Hay Plain

Leigh and Mulham (1977) and Mulham and Jones (1981) compiled a comprehensive species list for the riverine plain with notes on distribution and pastoral use. Moore (1953) conducted an ecological survey and produced a vegetation map of the south-eastern Riverina directly east of the present survey area. He discussed the concepts of climax and disclimax vegetation associations, identifying 23 communities (Moore 1953).

The riparian vegetation of the Murray River was mapped at 1:50 000 scale from Albury to Lake Alexandrina in South Australia (Margules & Partners *et al.* 1990). A total of 37 riparian communities were identified. Pressey *et al.* (1984) mapped the vegetation of the Lachlan–Murrumbidgee confluence situated in the west of the Hay Plain.

A survey of *Atriplex vesicaria* extent was conducted in 1987 by the Hay Soil Conservation Service, after widespread occurrences of dieback on the Hay Plain (Clift *et al.* 1987, Clift *et al.* 1989 and Semple 1989). The riverine plain was mapped for remnant Bladder Saltbush using data provided by local landholders (Soil Conservation Service of New South Wales unpubl.)

Sites are currently monitored throughout the Plain as part of the Rangeland Assessment Program by the New South Wales Department of Conservation and Land Management. Species have also been recorded for Willandra National Park by the New South Wales National Parks and Wildlife Service (1985–1988).

Methods

Mapping

The composition and extent of the present native vegetation, both remnant and modified was mapped for the Booligal–Hay and Deniliquin–Bendigo 1:250 000 map sheets (see back pocket). Black and white aerial photomosaics and photographs produced by the New South Wales Department of Lands (now the Land Information Centre of the Department of Conservation and Land Management) were used to define plant community boundaries. The photo-interpretation was checked and confirmed or modified by extensive site sampling and field traverses. Provisional vegetation maps were drafted at 1:100 000 scale and reduced to the published scale of 1:250 000. These and other sources of information used for compiling the maps are indicated in Table 2.

Some problems were encountered in interpreting the aerial photography of the Plain. Boundaries between some vegetation types, particularly shrublands and grasslands, are gradational. Mallee, riparian and other tree communities are more readily delineated on aerial photographs. Much ground truthing was thus required to define the extent of grassland and shrubland. Vegetation boundaries were often indirectly determined from the more distinct geomorphological features on the aerial images. While older photomosaics formed the basis for the mapping, contemporary vegetation was updated from recent stereo photography and LANDSAT imagery. Small remnants (smaller than 100 ha) were not mapped because of the scale employed for publication.

Survey

The vegetation survey was conducted over three years, with nine field trips totalling 15 weeks between February 1990 and October 1992. Of these, five were undertaken during the spring, three in autumn and one trip at the end of summer. The Booligal map area was surveyed in May 1992 during drought conditions and in October 1992 after limited winter rainfall. Fig. 6 indicates site locations and major field traverses across the mapped area.

Table 2. Information sources and data used in compiling the Booligal–Hay and Deniliquin–Bendigo 1:250 000 vegetation maps.

Source	Year	Data	Scale
Beadle, N.C.W.	1948	western NSW vegetation survey	1:1 013 760
New South Wales Department of Lands	1960–69	aerial photomosaics	1:50 000
Division of National Mapping (NATMAP)	1975–88	topographic maps	1:50 000 1:100 000 1:250 000
Pressey, R.L. *et al.*	1984	Cumbung Swamp vegetation survey	1:50 000
New South Wales Department of Lands	1986–90	stereo-paired aerial photos	1:49 000– 1:86 000
Soil Conservation Service of New South Wales (unpubl.)	1987	original maps and questionnaires from *Atriplex vesicaria* survey	1:250 000
Margules and Partners *et al.*	1990	Murray River riparian vegetation survey	1:50 000
Walker, P.J. (Department of Conservation and Land Management)	1991	Land Systems maps	1:250 000
Australian Centre for Remote Sensing	Dec. 1992	LANDSAT TM satellite imagery	1:250 000

The selection of sites was based on recognised photopatterns, accessibility and the condition of the vegetation on the ground. Additional areas of relatively undisturbed vegetation were sampled or checked on the advice of local experts. A total of 94 sites with a minimum area of 0.1 ha were fully sampled for vegetation, soil, disturbance and other environmental variables while species lists and descriptive information were collected for a further 153 sites. For the Hay and Deniliquin map areas, all species present were recorded within a sampling area of 0.2 ha (100 X 20 m). This was reduced to 0.1 ha (50 X 20 m) for the Booligal area after analysis of species area curves. Data were also collected on plant density, percentage cover, height of strata and relative strata cover. Percentage cover within the first 100 m^2 of the quadrat was assessed. Additional information on structure, landform, soils, disturbance and regeneration was recorded for each site. Soil samples and salinity data (using an EM-38 salinity meter) were collected for a subset of sites. Species lists were also made for numerous spot sites across the Plain.

Structural and floristic classification of the vegetation

The site data collected were used to describe the vegetation communities floristically and structurally. The structural classifications of Specht (1981) and Walker and Hopkins (1990) were employed. Community floristic composition was based on perennial vegetation and the vegetation units named after the dominant species of the tallest stratum. Where this was inappropriate, geological references were used in the naming of the community. Associated species are listed for each vegetation unit in order of abundance. Ground-cover species are listed separately where appropriate.

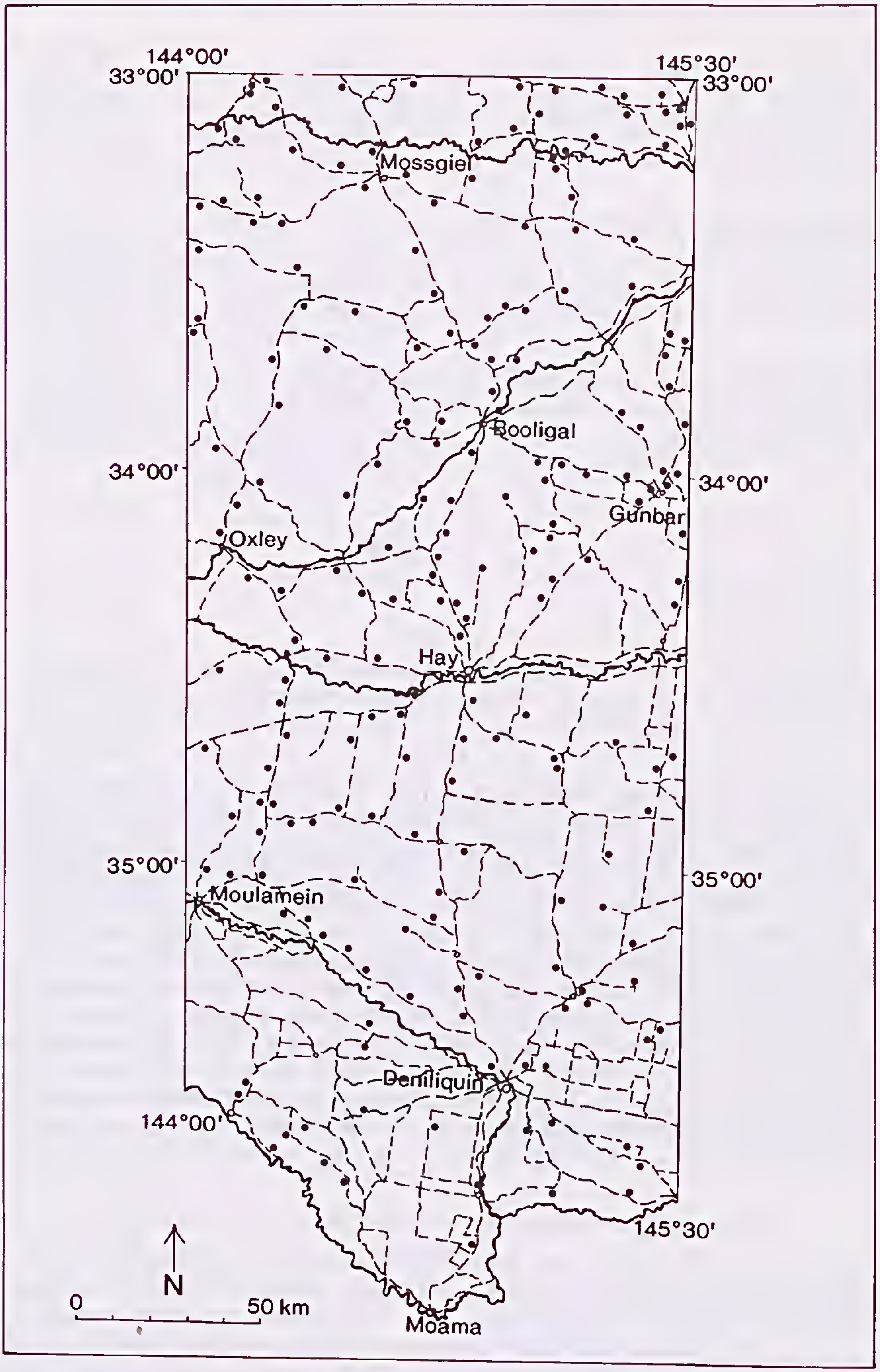

Figure 6. Site locations (dots) and major field traverses (dashed lines) across the mapped area (from fieldwork undertaken between February 1990 and November 1992).

The concepts of vegetation community and plant association have been variously defined. Beadle classified the vegetation of western New South Wales into major associations, each containing a number of types. The term 'type' is used to describe botanically uniform communities while an 'association' is defined as an aggregation of botanically related types (Beadle 1948). Beadle (1948) mapped the vegetation of western New South Wales at the 'association' level. In this survey, floristically uniform plant groupings are described and mapped as vegetation communities. This is equivalent to Beadle's 'type' ranking, and with the term 'association' as used by later authors (Beadle & Costin 1952, Moore 1953, Beadle 1981). The 'association' unit was redefined as a climax community in which the dominant stratum has a uniform floristic composition and structure (Beadle & Costin 1952). It should be noted that the term 'association' as used by Beadle (1948) was a more encompassing term, and is equivalent to the 'alliance' unit used in later publications to group floristically related associations (Beadle & Costin 1952, Moore 1953).

The botanical names used throughout the present survey are those currently recognised by the National Herbarium of New South Wales, and follow Harden (1990–92).

Community descriptions

Twenty-one vegetation communities are identified on the Booligal–Hay and Deniliquin–Bendigo 1:250 000 map sheets, represented by map units 1 to 29 (Table 3). Two cleared units are also recognised. Structural types range from grassland to open forest, including woodland, mallee shrubland and chenopod shrubland. Community structure is based on Specht (1981) # and Walker and Hopkins (1990) ##. An asterisk * indicates an exotic species. (B), (H), or (D) after a species indicates whether or not it is restricted to a particular map area: Booligal, Hay and Deniliquin–Bendigo respectively.

The vegetation communities

Map unit 1: Riverine Forest

Structure: open forest # and ##

Main species: *Eucalyptus camaldulensis* (River Red Gum)

Associated species: *Acacia stenophylla, Muehlenbeckia florulenta, Eucalyptus largiflorens, Chenopodium nitrariaceum, Acacia salicina, Eucalyptus microcarpa* (D), *Juncus ingens* (D), *Exocarpos strictus* (D), **Lycium ferocissimum*.

Ground-cover species: *Pratia concolor, Glinus lotoides, Oxalis perennans, Centipeda cunninghamii, Paspalidium jubiflorum, Alternanthera denticulata, Chamaesyce drummondii, Cotula australis, Marsilea drummondii, Carex appressa, Poa fordeana, Agrostis avenacea,* **Cotula bipinnata*, **Stellaria media* (D), **Solanum nigrum*, **Sonchus oleraceus*.

Landform: River and creek levees and adjacent flats, channelled plains and other areas subject to frequent or periodic flooding.

Soils: Heavy grey, brown and red clays.

Occurrence: This community occurs along the major river systems of the Murray, Edward–Wakool, Murrumbidgee and Lachlan Rivers and other rivers and creeks throughout the mapped area: (Figs 7 & 8). In the drier north, creeks and rivers tend to be fringed with *Eucalyptus largiflorens* (Black Box), although *Eucalyptus camaldulensis* will occur with Black Box wherever periodic flooding occurs. Dense stands of

Table 3. Plant communities of the Booligal (B), Hay (H) and Deniliquin–Bendigo (D) 1:250 000 map sheets with map unit and main species. Structure is based on Specht (1981) # and Walker & Hopkins (1990) ##. Equivalent map units used by Scott (1992) for the adjacent Balranald–Swan Hill map sheet are also indicated (Bal. No.).

No.	Plant Community	Main Species	Structure	Map	Bal. No.
1	Riverine Forest	*Eucalyptus camaldulensis*	open forest # & ##	BHD	1
2	Black Box Woodland	*Eucalyptus largiflorens*	woodland #; woodland - open woodland ##	BHD	2
3b	Dune-Crest Mallee	*Eucalyptus socialis*, *Eucalyptus dumosa*, *Triodia scariosa*	tall shrubland #; mallee shrubland - open mallee shrubland ##	B	3b
3d	Sandplain Mallee	*Eucalyptus socialis*, *Eucalyptus dumosa*	tall shrubland #; mallee shrubland - open mallee shrubland ##	B	3d
4	Belah–Rosewood	*Casuarina pauper*, *Alectryon oleifolius* subsp. *canescens*	low - low open woodland #; open woodland - isolated clumps ##	B	4
8	Black Bluebush	*Maireana pyramidata*	low - low open shrubland #; chenopod shrubland - sparse chenopod shrubland ##	BH	8
8p	Black Bluebush and Pearl Bluebush	*Maireana pyramidata*, *Maireana sedifolia*	low - low open shrubland #; chenopod shrubland - sparse chenopod shrubland ##	BH	9
11	Bladder Saltbush	*Atriplex vesicaria*	low - low open shrubland #; chenopod shrubland - open chenopod shrubland ##	BHD	11
12	*Sclerostegia tenuis*	*Sclerostegia tenuis*, *Disphyma crassifolium* subsp. *clavellatum*	low shrubland #; closed - open chenopod shrubland ##	BHD	-
13	Canegrass	*Eragrostis australasica*	tussock grassland # & ##	BHD	13
16	*Callitris* Mixed Woodland	*Callitris glaucophylla*	woodland - low open woodland #; woodland - isolated clumps ##	BHD	16
17	*Acacia melvillei* Woodland	*Acacia melvillei*	tall shrubland - low woodland #; shrubland - woodland ##	BHD	17

18	Lignum and *Chenopodium nitrariaceum*	*Muehlenbeckia florulenta,* *Chenopodium nitrariaceum*	low shrubland - open scrub #; open - closed shrubland ##	BHD	18
19	Old Man Saltbush	*Atriplex nummularia*	low - open shrubland #; chenopod shrubland - open chenopod shrubland ##	BHD	19
21	Cotton Bush	*Maireana aphylla*	low - low open shrubland #; chenopod shrubland - sparse chenopod shrubland ##	BHD	21
22	Dillon Bush	*Nitraria billardierei*	low - low open shrubland #; shrubland - sparse shrubland ##	BHD	22
23	Great Cumbung Swamp	*Phragmites australis,* *Senecio cunninghamii,* *Typha orientalis,* *Typha domingensis*	closed - open herbland/ grassland #; closed - open grassland/rushland/forbland ##	H	23
24	Grey Box Woodland	*Eucalyptus microcarpa,* *Allocasuarina luehmannii*	low woodland - woodland #; open woodland - woodland ## (occasionally to open forest # and ##)	D	-
25	*Acacia pendula* Woodland	*Acacia pendula*	low - low open woodland #; open woodland - woodland ##	BHD	-
26	White-top Grassland	*Danthonia caespitosa*	tussock grassland - open tussock grassland #; grassland - open grassland ##	BHD	-
27	Prior Stream Remnant Woodland	*Callitris glaucophylla,* *Hakea leucoptera,* *Hakea tephrosperma*	low open woodland #; open woodland - isolated trees ##	BHD	-
28	*Casuarina pauper/ Casuarina cristata* Intergrading Population	*Casuarina pauper/ Casuarina cristata* intergrades	low woodland - woodland #; open woodland - woodland ##	BH	-
29	Rocky Outcrop Woodland Complex	*Callitris glaucophylla,* *Eucalyptus intertexta,* *Eucalyptus vicina*	low woodland #; woodland to open woodland and open mallee woodland - shrubland ##	B	-
OA	Open Areas	various grasses, herb sand forbs	open herbfield #; grassland to forbland ##	BHD	OA

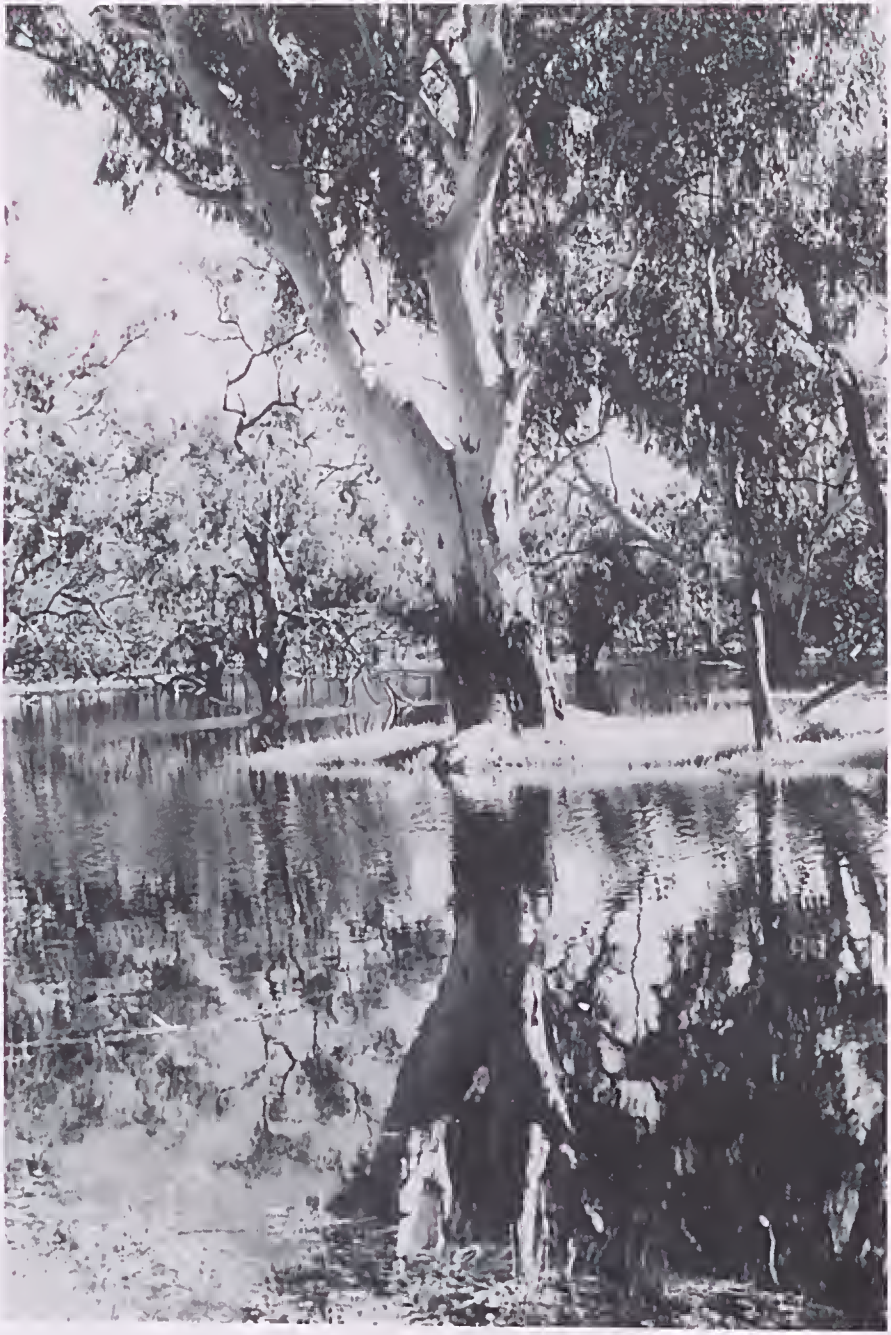

Figure 7. Flooded *Eucalyptus camaldulensis* open forest at Gum Creek, Boyds Bridge, south-east of Hay, in early spring (community 1).

Eucalyptus camaldulensis occur along the Murray and on its adjacent floodplain, particularly in the Barmah and Millewa State Forests, which are internationally recognised wetland habitats (Finlayson & Moser 1991). A more open *Eucalyptus camaldulensis* woodland is found on the channelled floodplain of the Lachlan River south-west of Booligal.

Condition: Old trees thinned with selective logging, resulting in a younger age class over much of the distribution of this community; forests subject to manipulated flooding regimes with regeneration greatly affected; limited weed infestation; many areas cleared for crop growing, especially in the Murray River area.

Notes: *Eucalyptus camaldulensis* requires periodic flooding for seedling germination and growth (Somerville 1988) while *Eucalyptus largiflorens* tolerates less frequent flooding and occurs on slightly higher ground on the floodplain, distant from the channel. Areas of *Eucalyptus largiflorens* that dominate these terrace landform elements have been mapped as a separate community (2). Rare hybrids of *Eucalyptus camaldulensis* and *Eucalyptus largiflorens* occur between Barham and Swan Hill.

Eucalyptus microcarpa (Grey Box) forms extensive stands within *Eucalyptus camaldulensis* forests in the Deniliquin area. In Werai State Forest north-west of Deniliquin, *Eucalyptus microcarpa* reaches open forest proportions. Within the Murray floodplain, higher areas of red-brown earths or sands occur, carrying much-cleared woodlands of *Callitris gracilis* subsp. *murrayensis* (Murray Cypress Pine) or *Callitris glaucophylla* (White Cypress Pine) (See Community 16). These sandhills scattered throughout the River Red Gum forest are commonly about twelve metres high and are older than the floodplain itself, having been there before the Cadell Tilt uplifting (Allen 1979). A small population of *Eucalyptus leucoxylon* subsp. *pruinosa* (unmapped) exists just north of Barham, adjacent to *Eucalyptus camaldulensis* and *Eucalyptus largiflorens* woodland and growing on grey-brown alluvial soil.

Eucalyptus camaldulensis may reach heights of up to 40 m and forms the only forest structural type in the area. A shrub layer is normally absent, with leaf and branch litter dominating the ground layer. Shrubs, if present, may include *Muehlenbeckia florulenta* (Lignum), *Chenopodium nitrariaceum* and **Lycium ferocissimum*. *Muehlenbeckia florulenta* and *Eragrostis australasica* may occur in intermittently flooded channels within the floodplain while areas of semi-permanent still water support rushlands of *Typha* spp. (Fig. 22), *Phragmites australis*, *Juncus* spp. and *Eleocharis* spp. The herbaceous layer varies seasonally and, as well as the species listed, may include *Rumex*, **Medicago*, *Echium* and **Xanthium* spp. together with exotic grasses such as **Hordeum leporinum* and **Lolium perenne*. River Red Gum forests are a good example of a unispecific community. Because of the regular flooding in their habitat, all other species are drowned and only *Eucalyptus camaldulensis* can survive (Allen 1979).

Much of the River Red Gum forest on the Murray River floodplain and areas along the Murrumbidgee River are under State Forest management and have been logged and grazed to various extents. Regeneration of *Eucalyptus camaldulensis* is poor in areas where grazing is a predominant land use. Changes in flooding regimes due to river regulation have led to a decline in the quality of stands (Margules & Partners *et al.* 1990). Natural regeneration is largely dependent on flooding (Somerville 1988) and river regulation is preventing this, for example, some stands have died along the Murray River (Allen 1979). Dense areas of *Eucalyptus camaldulensis* occur along the Murray River in the Barmah, Millewa, Perricoota and Koondrook State Forests and should be targeted for conservation. These forests are also an important archaeological resource, as they include canoe trees, camp sites, middens and burial grounds. A small area of River Red Gum is conserved within Goonawarra Nature Reserve on the Lachlan River south-west of Booligal but, with the exception of Kemendoc Nature

Reserve west of the mapped area, the community remains virtually unconserved along the Murray River in New South Wales. Some small Crown Reserves conserve River Red Gum forest areas, however these are usually discontinuous and generally not actively managed.

Map unit 2: Black Box Woodland

Structure: woodland #; woodland – open woodland ##

Main species: *Eucalyptus largiflorens* (Black Box)

Associated species: *Chenopodium nitrariaceum, Rhagodia spinescens, Atriplex nummularia, Enchylaena tomentosa, Einadia nutans, Muehlenbeckia florulenta.*

Ground-cover species: *Chamaesyce drummondii, Atriplex semibaccata, Atriplex leptocarpa, Oxalis perennans, Boerhavia coccinea, Centipeda cunninghamii, Alternanthera denticulata, *Verbena officinalis, Calotis scapigera.*

Landform: Uppermost floodplain levels, periodically flooded alluvial plains, ephemeral creeks and adjacent flats, dry-lake margins, depressions, drains and channels.

Soils: Heavy grey and brown clays, self-mulching or compact. Black Box woodland also occurs on the sandier soils of ancient rivers and former depressions (Semple 1990).

Occurrence: Black Box forms extensive woodlands on the terrace landform elements adjacent to major creeks and rivers across the mapped area (Fig. 9). It is also common in depressions, along major and minor creeks (especially north of the Murrumbidgee River) and fringing dry lakes. South of Moulamein and Conargo on the Deniliquin map, *Eucalyptus largiflorens* often occurs mixed with *Eucalyptus microcarpa* (Grey Box) and less commonly *Eucalyptus melliodora* (Yellow Box), gradually being replaced by the former further south on the floodplain.

Condition: Some tree dieback is apparent especially in irrigated areas; weed infestation common. Understorey generally intact and sparsely grazed, except where cleared in the southern irrigation areas.

Notes: *Eucalyptus largiflorens* is one of the most widespread and common trees in inland New South Wales, also extending into South Australia, Victoria and extreme southern Queensland. It grows on the less frequently flooded areas of the floodplain above the level of the adjacent River Red Gum forest. It also occurs in ribbon stands along intermittent creeks, fringing lakes, or as a line of very scattered individual trees along drainage lines. *Eucalyptus largiflorens* often occurs in depressions and other areas of restricted drainage within other vegetation communities such as *Callitris glaucophylla, Acacia pendula* and mallee woodlands.

The relatively open nature of this community has allowed for the development of an understorey of variable density and composition. The main understorey species in Black Box woodlands are *Chenopodium nitrariaceum, Rhagodia spinescens* and *Enchylaena tomentosa. Chenopodium nitrariaceum* often extends out beyond the Black Box floodplain to form extensive shrublands, although much has been cleared for irrigated cropping. *Atriplex nummularia* occasionally forms a tall understorey to *Eucalyptus largiflorens*. Where the community occurs in wetter, periodically flooded areas, *Muehlenbeckia florulenta* may be the major understorey component.

Dieback of *Eucalyptus largiflorens* is a problem in heavily irrigated areas, particularly adjacent to the Murray River. In their survey of riparian vegetation, Margules and Partners *et al.* (1990) reported that trees were generally in poor condition over most

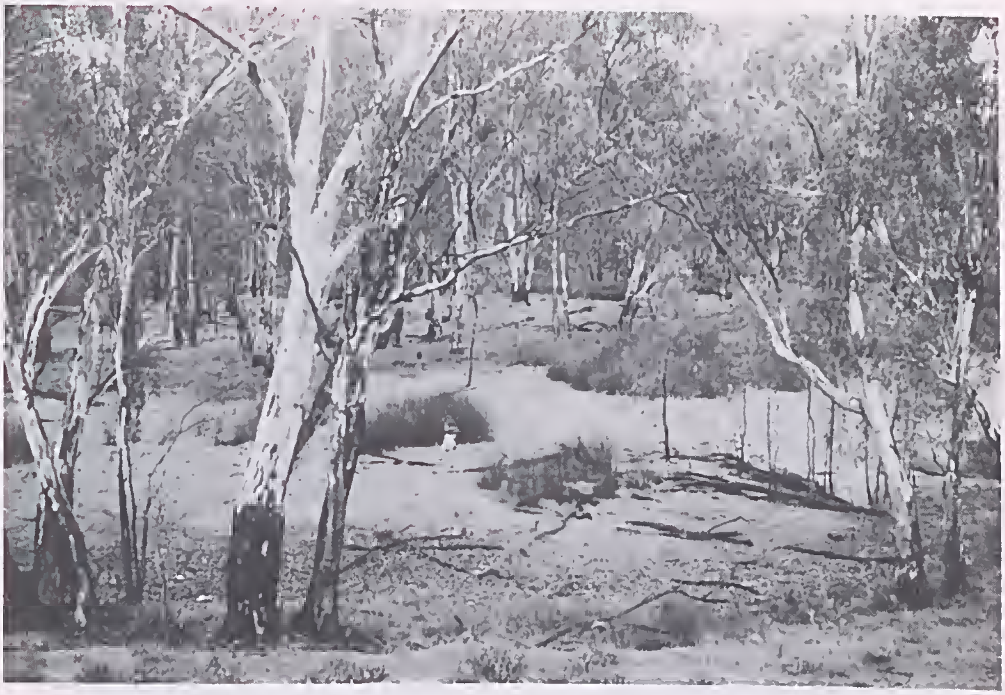

Figure 8. *Eucalyptus camaldulensis* forest with *Juncus ingens* understorey and ground cover of *Scleranthus miniscula* and *Stellaria media*; Edward River, Mathoura, in late winter (community 1).

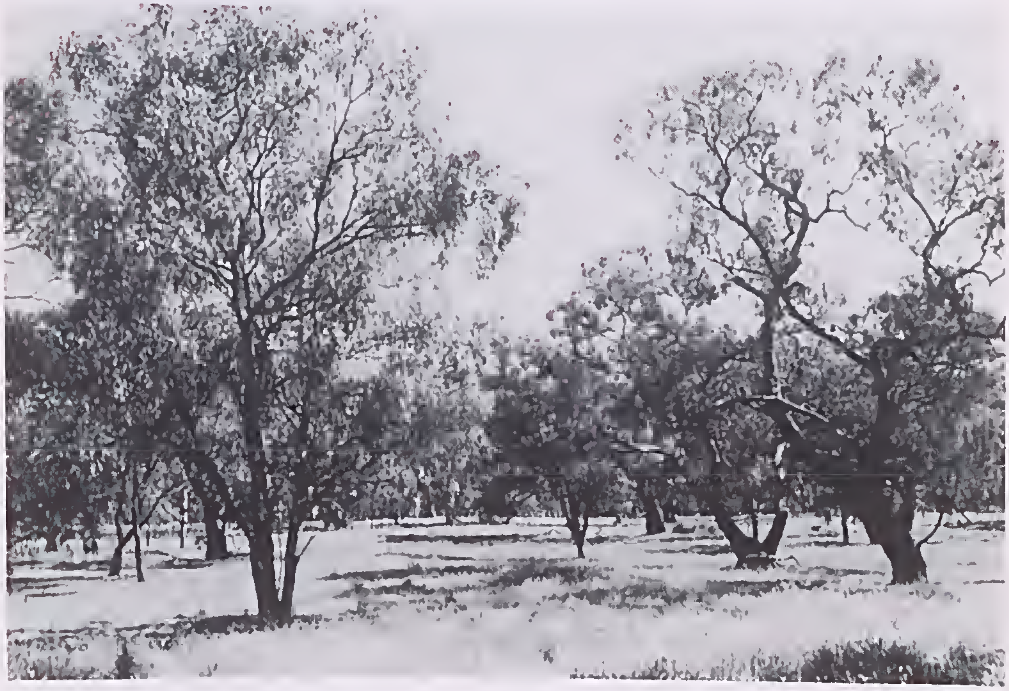

Figure 9. Open *Eucalyptus largiflorens* woodland with grassy understorey of *Hordeum leporinum* and *Lolium perenne* on 'Bertangles', east of Hay, in early spring (community 2).

of their distribution along the whole of the Murray River, with Black Box in the far western reaches the worst affected. Soil salinisation from rising local water tables and salty groundwater inflows is considered a major problem along the river. Local cases of dieback around Deniliquin in the Edward–Wakool river system have also been reported (M. Driver, Greening Australia, pers. comm.). Salinity may be a contributing factor, although the causes of these and other dieback events in dryland areas are currently under investigation.

Logging has been a common practice in Black Box communities and the timber used for fencing. The area around Hay has been particularly affected, although small clumps have been retained in paddocks for stock shelter (Semple 1990). Sheep grazing appears to have limited regeneration of Black Box along the Murray River, while previous logging has led to a decline in mature trees of the species (Margules & Partners *et al.* 1990, Treloar 1959). A section of Willandra Creek supporting a Black Box woodland with a dense *Acacia stenophylla*, *Chenopodium nitrariaceum* and *Muehlenbeckia florulenta* understorey is conserved within Willandra National Park on the Booligal map area. A small area of *Eucalyptus largiflorens* associated with the Lachlan River is also conserved within Goonawarra Nature Reserve south-west of Booligal. The community is considered poorly conserved in New South Wales (Murray–Darling Basin Ministerial Council 1987).

Map unit 3: Mallee

Structure: tall shrubland to low woodland #; mallee shrubland to open mallee shrubland (rarely open mallee woodland) ##

'Whipstick' mallee is a low, stunted multi-stemmed growth form, indicating a sandy soil of low fertility and commonly occurring on the dune crests. 'Bull' mallee, a taller form with fewer stems, indicates a more fertile and less sandy soil and occurs in the heavier soils of the swales (Beadle 1948, Noble *et al.* 1980).

Main species: *Eucalyptus socialis* (Pointed Mallee) (B), *Eucalyptus dumosa* (Congoo Mallee) (B).

Associated species: *Eucalyptus gracilis* (B), *Eucalyptus leptophylla* (B), *Senna artemisioides* subsp. *filifolia*, *Senna artemisioides* subsp. *petiolaris*, *Dodonaea viscosa* subsp. *angustissima*, *Acacia colletioides* (B), *Eucalyptus intertexta* (B), *Eucalyptus populnea* subsp. *bimbil* (B).

Callitris glaucophylla and *Acacia melvillei* as well as *Casuarina pauper* with *Alectryon oleifolius* form local communities within the mallee.

The following species are associated with particular geomorphological variation within the mallee:

3b Dune-Crest Mallee: *Triodia scariosa* (B), *Lomandra effusa* (B), *Olearia pimeleoides* (B), *Eremophila glabra* (B), *Eremophila sturtii* (B), *Acacia wilhelmiana* (B).

3d Sandplain Mallee: *Maireana pyramidata*, *Enchylaena tomentosa*, *Dissocarpus paradoxus*, *Rhagodia spinescens*.

Note: These shrubs occur more commonly in the Sandplain Mallee in the west of the mapped area. The Sandplain Mallee of the north-east supports a different shrub layer of mostly *Senna*, *Dodonaea* and *Acacia* species, with a high bark litter ground component.

Landform: Level to undulating sandplains and irregular dunefields with low, discontinuous, linear dunes.

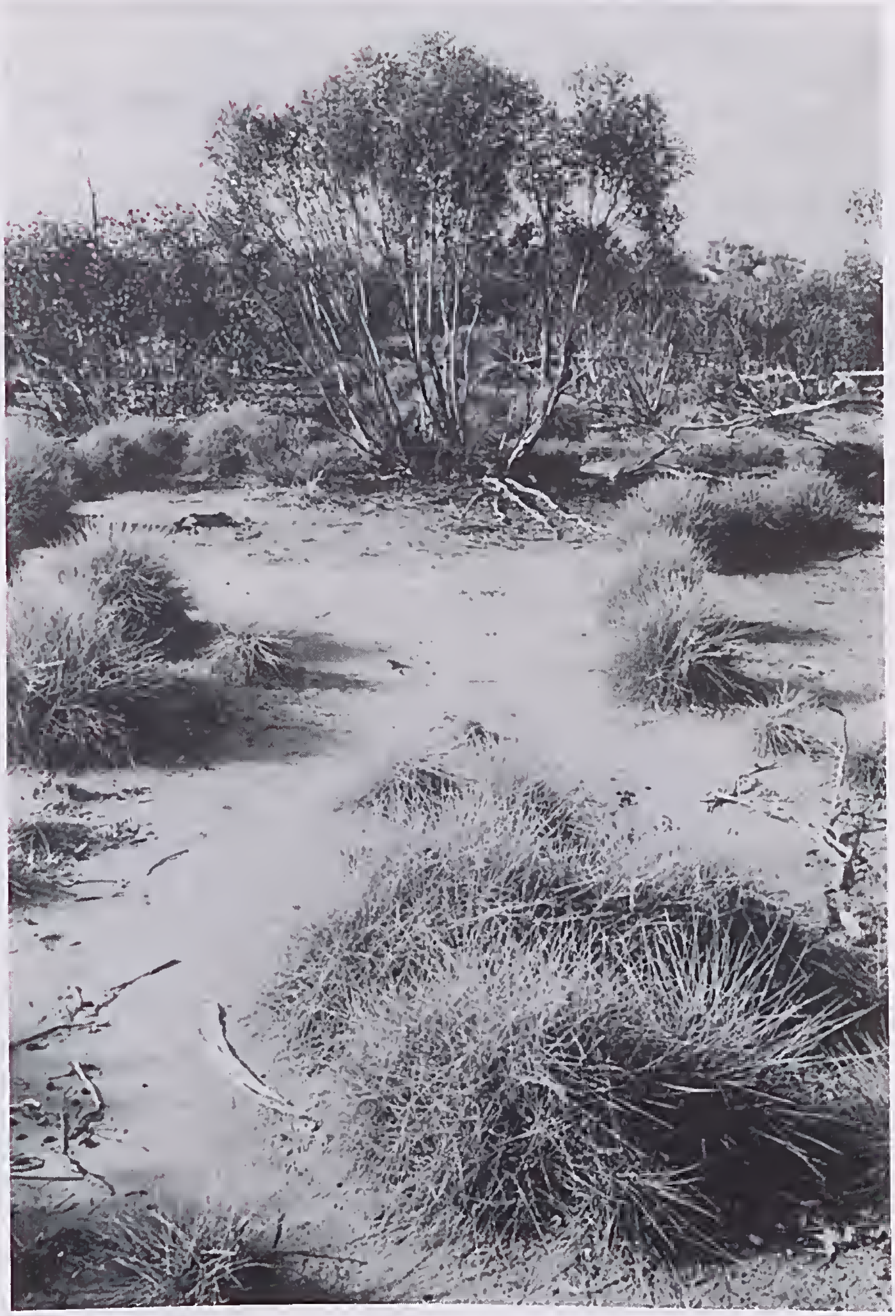

Figure 10. Mallee shrubland with *Eucalyptus socialis* and *Triodia scariosa*, on dune-crest south of Roto in mid-spring (community 3b).

Soils: Calcareous red earths with sandy loam to clay loam surface and red desert loams derived from aeolian materials (Scriven 1988a, Eldridge 1990).

Occurrence: Two disjunct areas of mallee occur on the Booligal map area. In the north-eastern sector, the mallee is characterised by sandplains and low irregular dunes with some Dune-Crest mallee (Fig.10) and interspersed with higher sandhills supporting *Callitris glaucophylla* and undulating areas of Belah–Rosewood. South of Hillston the mallee is of the 'bull'-type, with large, few-stemmed trees (Fig. 11). Due to extensive cropping in this area the mallee is very much of a remnant nature with a cleared understorey. North of Hillston and extending north and north-west to Roto and Trida railway sidings, extensive stands of whipstick mallee occur with a well-developed shrubby understorey. The second area of mallee occurs in the aeolian-alluvial geomorphological transition zone in the west. Aeolian sandplains carrying mallee with a *Maireana pyramidata* (Black Bluebush) understorey occur on the south-western edge of the Booligal map. This is primarily within Belah–Rosewood country (see Community 4) along the Clare-Oxley and Hatfield roads. Extensive dunefields supporting mallee on the dune crests and Belah–Rosewood in the swales occur further west.

Condition: Many areas (especially south of Hillston) severely cleared or thinned; dunes largely cleared; some soil erosion due to rabbit infestation and some scalding in open areas; areas of woody shrubs present; some areas subject to wildfire; few old stands remain, mostly of the 'whipstick' form. Dense mallee areas with intact understoreys exist along the railway lines in the north-east.

Notes: In New South Wales, mallee mainly occurs in the far south-west largely intact, and in a central area, much of which has been cleared for cereal growing and is now roughly bounded by Ivanhoe, Cobar and Condobolin (Scriven 1988a). *Eucalyptus socialis* and *Eucalyptus dumosa* are amongst the main species present in these mallee lands, with structural variations in different habitats (Lawrie & Stanley 1980). In the east of the mapped area, stands of *Callitris glaucophylla* and Belah–Rosewood occur intermixed with the mallee. *Eucalyptus intertexta* (Western Red Box), and *Eucalyptus populnea* subsp. *bimbil* (Bimble Box), also occur occasionally. A different mallee community exists in the west of the mapped area in the transition zone from alluvial to aeolian landforms. Here on the sandplain the mallee has a low, open, shrubby understorey of *Maireana pyramidata, Rhagodia spinescens* and *Enchylaena tomentosa. Eucalyptus socialis* and *Eucalyptus dumosa* are the main mallee species in both landform types occurring on the mapped area.

Ground litter is often high in communities that have remained unburned for some years. Chenopods form an understorey where the soils are higher in clay content, such as on sandplains and swales. *Triodia scariosa* occurs in the understorey on sandier sites such as dune crests. Large woody shrubs such as *Dodonaea, Senna* and *Acacia* species are common understorey components in the north-eastern mallee of the mapped area. To stimulate pasture growth, many graziers reduce mallee density by clearing (chaining) and burning (Semple & Eldridge 1989).

Map unit 4: Belah–Rosewood

Structure: low woodland – low open woodland #; open woodland – isolated clumps ##

Main species: *Casuarina pauper* (Belah), *Alectryon oleifolius* subsp. *canescens* (Rosewood). *Alectryon oleifolius* subsp. *elongatus* occurs less commonly; this subspecies has a more eastern distribution and grows on heavier soils (L. Johnson pers. comm., Harden 1990–1992).

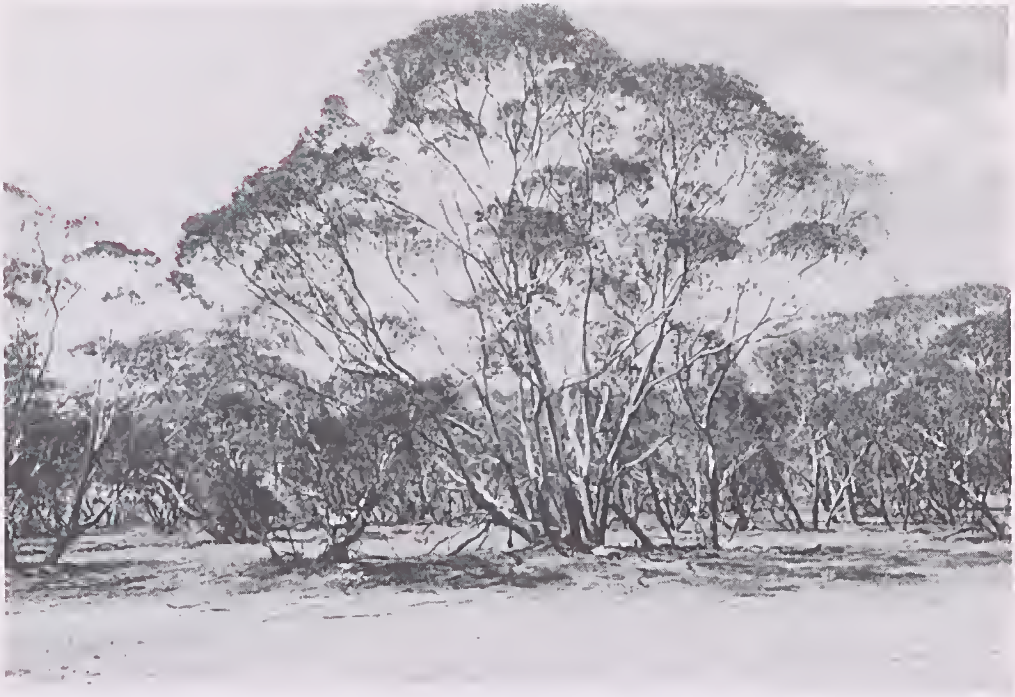

Figure 11. Remnant Sandplain Mallee (community 3d) of *Eucalyptus socialis, Eucalyptus dumosa* and *Eucalyptus gracilis*, south-west of Hillston along McKinley Road, in mid-spring.

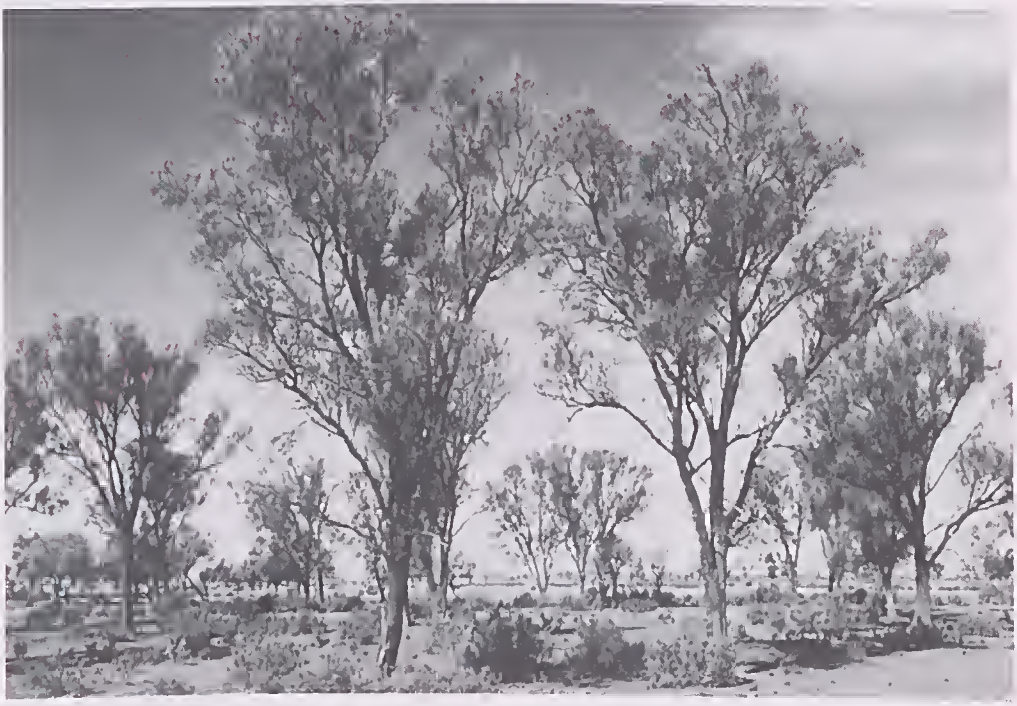

Figure 12. Belah-Rosewood open woodland (community 4) with *Casuarina pauper* in the foreground and a low *Maireana pyramidata* understorey; just west of 'Belgium Park' south of Ivanhoe, at the end of autumn.

Associated species: *Maireana pyramidata, Geijera parviflora, Exocarpos aphyllus, Rhagodia spinescens, Acacia victoriae* (B), *Acacia melvillei, Dissocarpus paradoxus, Maireana sedifolia, Myoporum platycarpum, Maireana humillima* (B).

Landform: Level to undulating sandplains and aeolian dunes.

Soils: Calcareous earths, mainly of red to red-brown loam to loamy sand. Solonised brown soils to sandy red earths (Cunningham *et al.* 1981). Reddish-brown sands and texture-contrast (duplex) soils (Scriven 1988b). Red-brown soils with light-textured topsoil and calcareous subsoil (Wilson & Johnson 1989).

Occurrence: Belah–Rosewood occurs across the north and in the west to north-west of the Booligal map area (Fig. 12). The densest continuous areas of Belah–Rosewood clumps occur along the Ivanhoe–Balranald Road in the north-west of the map and east of Mossgiel along the Alma Lake and East Clare roads. An area of Belah–Rosewood with a low shrubby understorey of *Maireana brevifolia* was observed south of Conoble siding. Scattered trees of *Flindersia maculosa* were also seen within an open Belah–Rosewood community south-east of Ivanhoe. Dense *Casuarina pauper* was also observed in a distinct tier on the lower slopes of Warranary Hill, a rocky outcrop in the far north-east of the Booligal-Hay map (Community 29).

Condition: Scalding and soil erosion, often severe, due to rabbit infestation; many bare areas and trees generally thinned; areas of woody shrubs present; few stands with healthy understorey shrubs; heavily grazed.

Notes: *Casuarina pauper* and *Alectryon oleifolius* are distributed in monospecific groves within this community with little mixing of the two species. Groves or clumps of trees may be many metres apart. An open *Maireana pyramidata* understorey is common, with *Maireana sedifolia* on the calcareous soils at higher elevations. Heavy grazing of these areas has resulted in the thinning and clearing of much of the understorey and the undermining of the sandier soils by rabbits has caused further degradation. The soils are also susceptible to scalding. This community occurs on the western-most edge of the riverine plain at the transition from alluvial to aeolian landscapes.

Callitris glaucophylla, Pittosporum phylliraeoides, Hakea leucoptera and *Hakea tephrosperma* occupy sandier areas of higher elevation within this community. *Acacia melvillei* groves are also common on sandy-loam areas. Mallee (Community 3) may intermix with Belah–Rosewood in deeper sands at the western and far north-eastern edges of the mapped area. *Casuarina pauper* and *Alectryon oleifolius* also occur throughout the mapped area as isolated trees or small groves, especially within the mixed *Callitris*-dominated woodlands of prior streams and source-bordering dunes (Communities 16 and 27).

This community is dominated by *Casuarina pauper* which is closely related to, and of a smaller and poorer form than *Casuarina cristata*. Both species were included in Beadle's concept of *Casuarina lepidophloia* (Beadle 1948) and referred to by other authors as *Casuarina cristata* (Cunningham *et al.* 1981). *Casuarina cristata* (Belah) and *Casuarina pauper* (Black Oak) are now treated as distinct species (Wilson & Johnson 1989). An intergrading population of *Casuarina cristata* and *Casuarina pauper* occurs in the east of the mapped area (see Community 28). *Casuarina cristata* is a more central-eastern species in New South Wales and southern Queensland in contrast to the more western distribution of *Casuarina pauper*, which extends across South Australia into Western Australia (L. Johnson pers. comm.).

Tree clumps of *Casuarina pauper* and particularly of *Alectryon oleifolius* often survive by suckering. Regeneration is prevented by grazing (Semple & Eldridge 1989), while the regeneration potential of *Alectryon oleifolius* is also reduced by insect seed-embryo predation (Wisniewski & Parsons 1986). Belah around Mildura and Ivanhoe is increasingly cut for timber and cleared for cropping, although felling is costly and difficult because of the robust nature of the trees (Semple & Eldridge 1989).

Map unit 8: Black Bluebush

Structure: low shrubland – low open shrubland #; chenopod shrubland – sparse chenopod shrubland ##

Main species:

8. *Maireana pyramidata* (Black Bluebush)

8p. *Maireana pyramidata*, *Maireana sedifolia* (Pearl Bluebush)

Associated species: *Maireana sedifolia*, *Rhagodia spinescens*, *Enchylaena tomentosa*, *Atriplex lindleyi*, *Dissocarpus paradoxus*, *Maireana georgei*, *Stipa nitida*, *Stipa scabra* subsp. *falcata*, *Stipa scabra* subsp. *scabra*, *Eragrostis dielsii*, other *Atriplex* spp. and *Sclerolaena* spp.

Landform: Low sandy rises, undulating plains, lunette remnants, prior stream levees.

Soils: Calcareous sands and loams, red-brown duplex soils with sandy topsoils and clayey subsoils. The distribution of *Maireana pyramidata* and *Maireana sedifolia* appears to be determined by soil calcareousness. Black Bluebush dominates where limestone lies at a depth of 1.2 m or more below the soil surface while soils containing shallower limestone will also support Pearl Bluebush (Beadle 1948).

Occurrence: This shrubland community is common in the north to north-west of the mapped area, particularly on the Booligal map area, where the country becomes undulating and duplex soils predominate (Fig. 13). Smaller rises with *Maireana pyramidata* occur throughout the mapped area, particularly on scalded prior stream levees and flats. Large and often dense areas of *Maireana pyramidata* with *Maireana sedifolia* occur north of Oxley, west of Alma Lake and south of Ivanhoe, although *Maireana sedifolia* does not usually occur as the dominant species in these localities (Fig. 14).

Condition: Severe to moderate soil erosion due to rabbit infestation with many bare areas; severe scalding on source-bordering dunes and lunettes; moderately grazed. Dense, relatively healthy areas exist in the north-west of the mapped area, although these may be periodically subject to caterpillar defoliation and possible dieback.

Notes: This community often grades into *Atriplex vesicaria* or *Atriplex nummularia* on flats and lower areas. Two condition classes of *Maireana pyramidata* were observed within the mapped area. A very open shrubland of scattered, often sparse shrubs occurs on raised scalded areas, lunettes, prior stream levees and cleared areas. Dense continuous stands, often with *Maireana sedifolia*, occur on raised areas with deeper sandy or sandy-loam soils.

Maireana sedifolia (Pearl Bluebush) tends to occur on calcareous soils where limestone nodules lie within 60 cm of the surface and dominates where limestone exists within the first 30 cm (Beadle 1948). *Maireana pyramidata* usually occurs on sandy soils which are alkaline but contain little lime (Dalton 1988). Pearl Bluebush was not mapped as a separate community because of its relatively small extent and has been included under this map unit. The existence of *Maireana sedifolia* within *Maireana pyramidata* shrubland is indicated (map unit 8p). Both species also occur as an understorey to Belah–Rosewood, commonly extending into adjacent areas of this woodland and occasionally into mallee. *Maireana pyramidata* is a common species on the veneer of

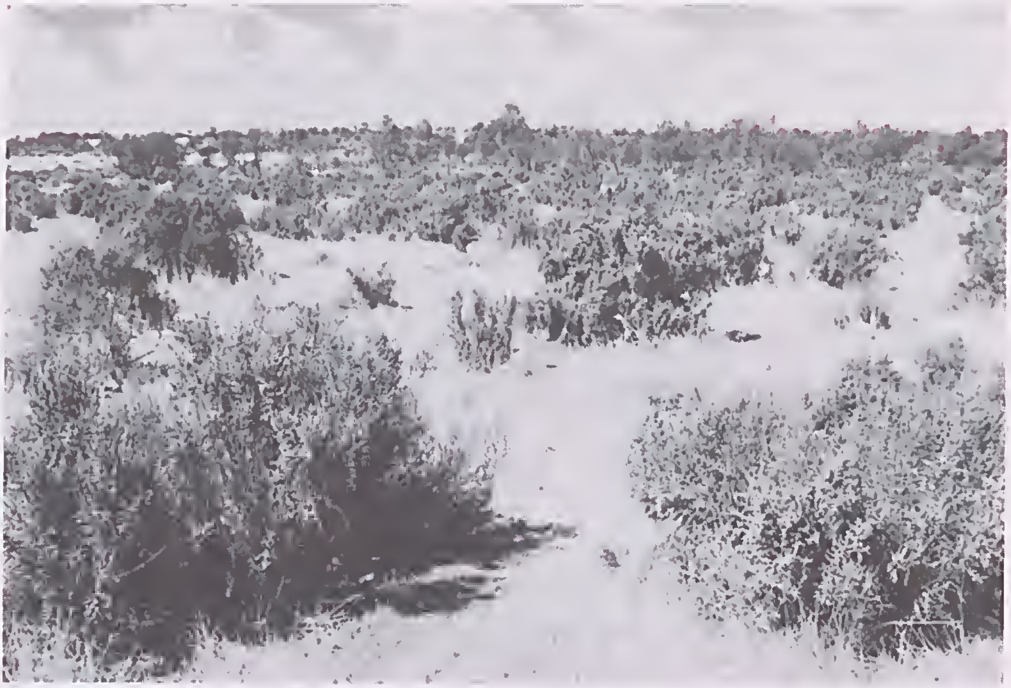

Figure 13. *Maireana pyramidata* shrubland (community 8) with a sandhill supporting *Eremophila longifolia* and *Dodonaea viscosa* subsp. *augustissima* in the background; Tchelery Woolshed west of Booroorban, at the end of summer.

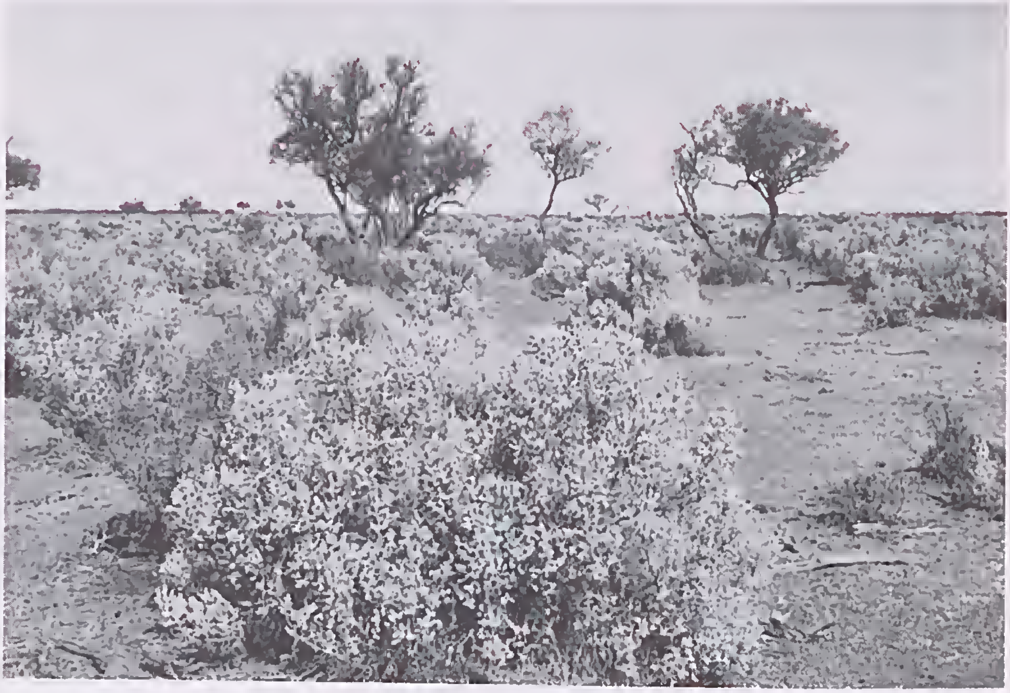

Figure 14. *Maireana sedifolia* shrubland (community 8p) with scattered *Casuarina pauper* and *Maireana pyramidata*, west of Alma Lake at the end of autumn.

aeolian material that indicates the transition from riverine or lacustrian landforms. *Maireana sedifolia* becomes the dominant further west where calcareous earths are more common (Beadle 1948, Fox 1991).

The coarse-textured duplex soils supporting bluebush communities are highly susceptible to wind erosion and rabbit infestation. Little clearing of bluebushes occurs in the Western Division because of their drought forage value (Semple & Eldridge 1989). Clearing of dense stands is not permitted under Cultivation Permits issued by the Western Lands Commissioner. This community remains unconserved on the Hay Plain.

Map unit 11: Bladder Saltbush

Structure: low shrubland – low open shrubland #; chenopod shrubland – open chenopod shrubland ##

Main species: *Atriplex vesicaria* (Bladder Saltbush). Due to incomplete distributional data subspecies (Harden 1990–92) have not been recognised in the present survey.

Associated species: *Sclerostegia tenuis, Malacocera tricornis, Disphyma crassifolium* subsp. *clavellatum, Minuria cunninghamii, Maireana aphylla, Sclerolaena tricuspis, Sclerolaena muricata, Ixiolaena tomentosa, Eragrostis australasica, Sclerolaena brachyptera, Sclerolaena bicornis* var. *bicornis, Sclerolaena intricata, Leptorhynchos panaetioides, Calocephalus sonderi, Frankenia connata, Maireana decalvans, Dissocarpus biflorus* var. *biflorus.*

Other common associate species which vary seasonally include:

Atriplex lindleyi, Atriplex pseudocampanulata, Rhodanthe corymbiflora, Plantago cunninghamii, Podolepis muelleri, Daucus glochidiatus, Sida trichopoda, Maireana pentagona, Sclerolaena stelligera, Brachycome linearilοba, Vittadinia cuneata var. *cuneata, Chloris truncata, Sporobolus caroli, Agrostis avenacea.*

Landform: Level to depressed alluvial plains.

Soils: Deep, grey, self-mulching and cracking clays to red clay-loam. Grey clays, clay-loams to sandy loams overlying clay (Knowles & Condon 1951). May also occur in sandy deposits.

Occurrence: *Atriplex vesicaria* forms the dominant vegetation community over the mapped area (Figs. 15 & 16). It is believed to have once covered vast areas of the Hay Plain but that excessive grazing has led to its rapid decline (Beadle 1948, Knowles & Condon 1951). Several dieback events over the past decade have seen a further decline in extent of the species. Post-dieback distribution of *Atriplex vesicaria* has been mapped. The largest continuous stands occur north of Hay and west to north-west of Booligal, particularly around One Tree, Oxley, 'Freshwater' and 'Culpataro'. Only small remnant patches exist on the Deniliquin map, these being mainly north of Billabong Creek. The New South Wales Soil Conservation Service established five experimental and regeneration areas on the saltbush plains between 1950 and 1952 which remain fenced today and contain regenerated saltbush (Dalton 1988).

Atriplex vesicaria stands extend west to Balranald and north to about 20 km south of Ivanhoe. The area occupied by Bladder Saltbush stands on the riverine plain was estimated at approximately 1.1 million hectares, decreasing to 0.5 million hectares by the end of 1983 with subsequent dieback (Clift *et al.* 1987). Smaller areas of the community occur further north and west, for example on some of the relict lakes of the Willandra Lakes system. Some saltbush occurs in north-western Victoria as discrete areas along the Murray River (Dalton 1988). *Atriplex vesicaria* shrublands also occur on the treeless plains around the Barrier Range in north-western New South

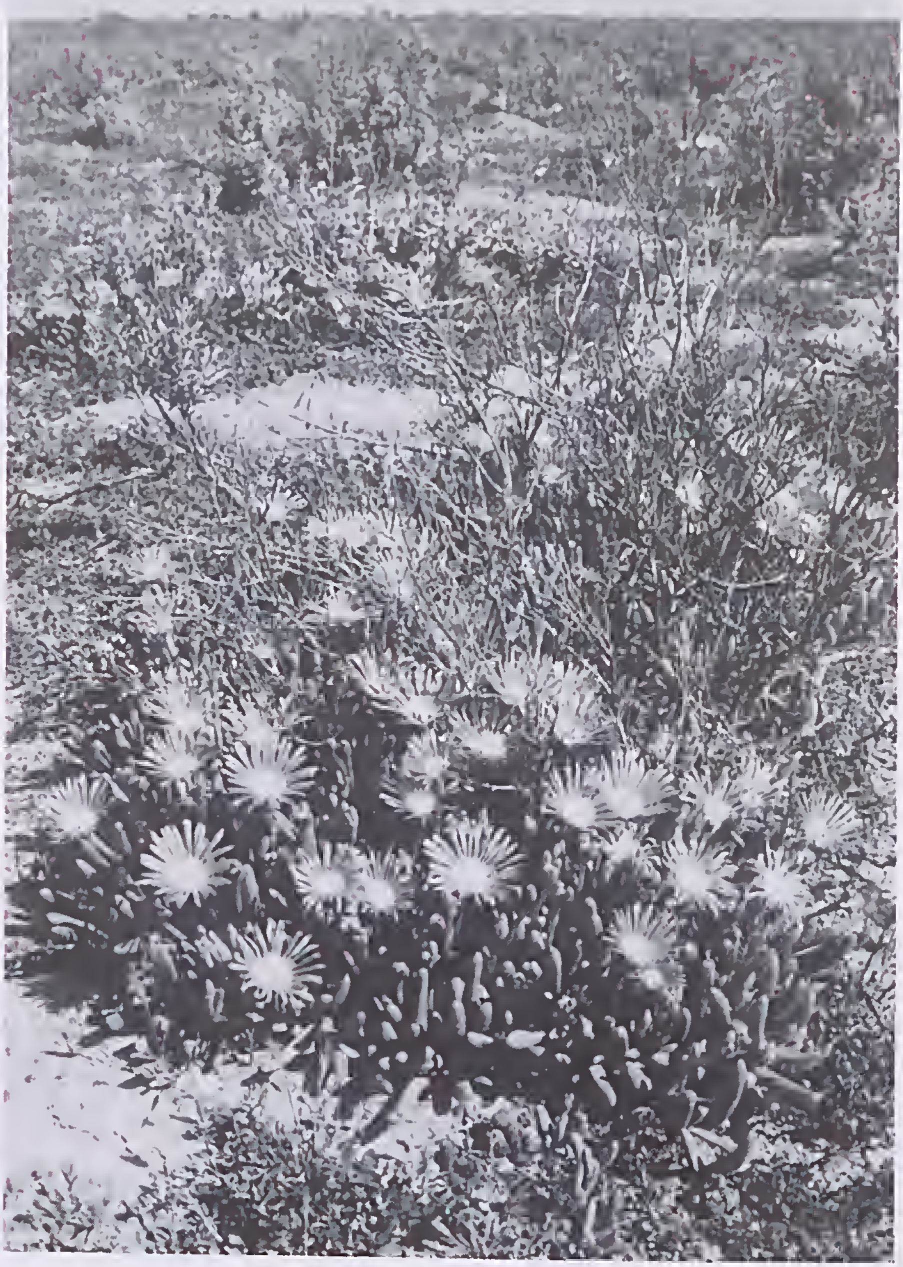

Figure 15. *Disphyma crassifolium* subsp. *clavellatum* growing amongst *Atriplex vesicaria* shrubs (community 11) south-east of Booligal, in mid-spring.

Wales but, unlike those on the Hay Plain, occur on sandy to sandy loam surface soils (Beadle 1948).

Condition: Seriously affected by widespread dieback; moderately to heavily grazed; shrub densities reduced and many areas degraded to *Maireana aphylla* or copperburr (*Sclerolaena* spp.) shrublands.

Notes: The decline of the once-vast *Atriplex vesicaria* shrublands began with the opening-up of western New South Wales to pastoral activity in the mid-1800s. Overgrazing and drought has seen the elimination of the species over a wide area (Knowles & Condon 1951). In many cases it has been replaced by *Maireana aphylla*, *Sclerolaena* species, annual saltbush species and introduced grasses. Degraded communities within Bladder Saltbush shrubland as listed by Beadle (1948) include *Maireana aphylla, Atriplex lindleyi, Sclerolaena muricata*, annuals and *Nitraria billardierei.*

Atriplex vesicaria on the Hay Plain was affected by large-scale dieback from 1977 to 1983 (Clift *et al.* 1987, Clift *et al.* 1989, Semple 1989). This resulted in a 53 per cent decrease in area of the community, from 1 130 000 ha to 531 000 ha (Semple 1989). A second dieback event is presently occurring in these remnant regions (September 1991). The worst-affected areas are south-west to north-west of Booligal with stands directly west of Booligal particularly affected. The causes of these dieback events are discussed in the 'Natural modifications' section of the Discussion.

A close associate of *Atriplex vesicaria* is *Sclerostegia tenuis*, which replaces the former in depressed, saline situations (see Community 12). Large patches of *Eragrostis australasica* often occur in depressions within both these shrubland communities. Bluebush rises often grade into Bladder Saltbush shrubland at lower levels. *Atriplex vesicaria* often occurs mixed with *Atriplex nummularia* on flat to low-lying sites.

Atriplex vesicaria is palatable to sheep and is often the only forage plant available during drought. It is considered highly valuable from a fodder point of view and is high in protein and salt content. The woody stems are brittle and very prone to mechanical damage with overgrazing (Knowles & Condon 1951). Good regeneration of *Atriplex vesicaria* follows high autumn or winter rainfall, however the high temperatures that follow summer rainfall inhibit germination and damage the soil seed source (Knowles & Condon 1951).

Map unit 12: *Sclerostegia tenuis*

Structure: low shrubland #; closed – open chenopod shrubland ##

Main species: *Sclerostegia tenuis* (Slender Glasswort), *Disphyma crassifolium* subsp. *clavellatum* (Round-leaf Pigface).

Associated species: *Atriplex vesicaria, Eragrostis australasica, Sclerolaena tricuspis, Malacocera tricornis*, annual *Atriplex* spp., *Sclerolaena muricata, Sclerolaena brachyptera, Osteocarpum acropterum* var. *deminuta, Minuria cunninghamii.*

Landform: Saline flats and depressions, depressed alluvial plains.

Soils: Clay soils in saline situations.

Occurrence: On depressed saline flats mostly in the west of the mapped area. Large patches occur with *Atriplex vesicaria* around Oxley and 'Corrong' on the Hay map and west of Dry Lake.

Condition: Some dieback apparent; moderately to heavily grazed with many areas degraded to *Maireana aphylla* or copperburr (*Sclerolaena* spp.) shrublands.

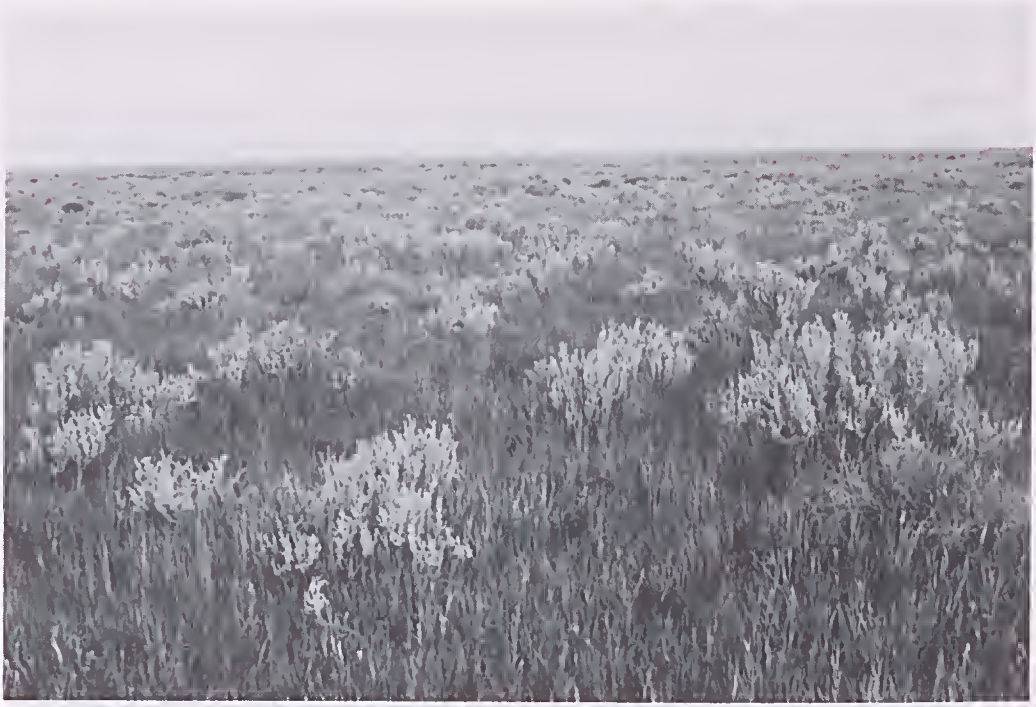

Figure 16. Open *Atriplex vesicaria* shrubland (community 11) south of Hay, with annual grass cover of *Hordeum leporinum* and *Lolium perenne*, in early spring.

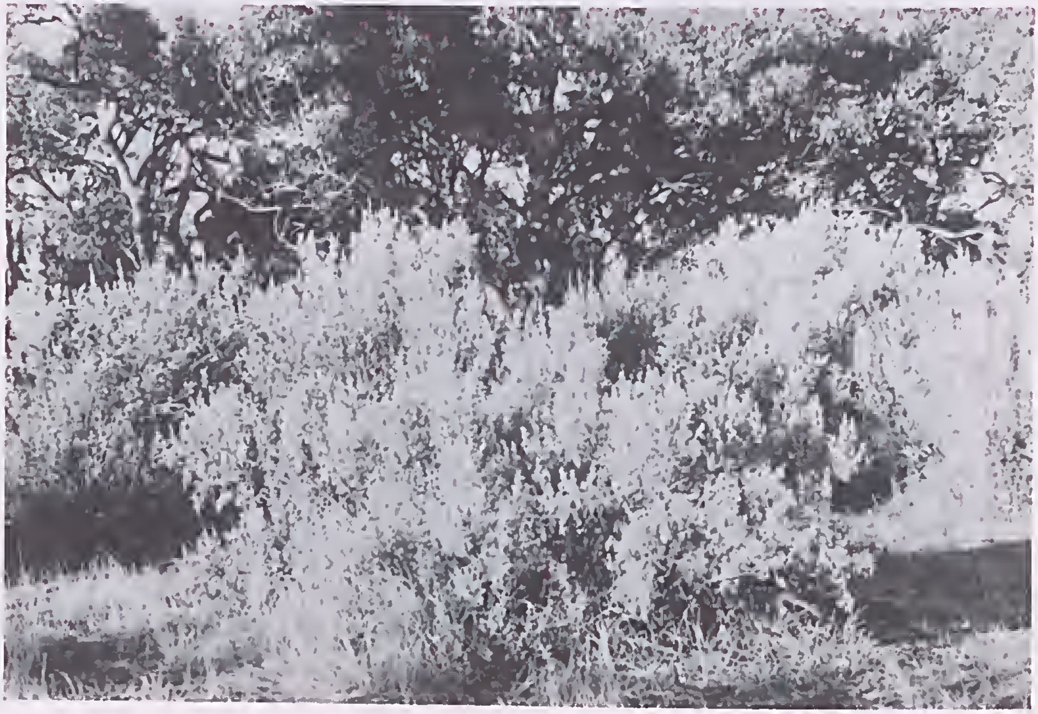

Figure 17. *Atriplex nummularia* shrubland (community 19) adjacent to Black Box woodland, on 'Mywurlie' station, north-east of Hay, at the end of summer.

Notes: This community is closely allied to *Atriplex vesicaria* shrubland into which it generally grades. *Sclerostegia tenuis* becomes the dominant species in more saline situations and the community is particularly well-developed on the lower alluvium around Lake Victoria and other dry lakes and saltpans further west (Fox 1991). It is considered a highly salt-tolerant species, being capable of colonising highly saline environments where no other species will grow (Beadle 1948). *Sclerostegia tenuis* often forms dense mats below Black Box woodland and has decreased significantly in abundance due to grazing and trampling by stock (Cunningham *et al.* 1981).

Map unit 13: Canegrass

Structure: tussock grassland # and ##

Main species: *Eragrostis australasica* (Canegrass)

Associated species: *Eleocharis palleus, Juncus flavidus, Juncus aridicola, Muehlenbeckia florulenta, Disphyma crassifolium* subsp. *clavellatum, Chenopodium nitrariaceum.*

Landform: Alluvial plains with depressions and other low-lying areas subject to intermittent flooding or ponding such as swamps, tabledrains and claypans.

Soils: Slightly saline, compact, heavy grey clays.

Occurrence: *Eragrostis australasica* occurs throughout the mapped area. It is particularly common in saline depressions within *Atriplex vesicaria* shrubland north of Hay, on the Lachlan River floodplain between Oxley and Booligal and in tabledrains and depressions along the major roads in low-lying and irrigated areas.

Condition: Some areas cleared, many degraded to copperburr (*Sclerolaena* spp.) shrubland.

Notes: *Eragrostis australasica* tolerates regular, but not prolonged flooding, with *Muehlenbeckia florulenta* (Lignum) occupying the wetter areas (Semple 1990). *Chenopodium nitrariaceum* and *Atriplex nummularia* may be present around the edges of Canegrass swamps.

Areas of *Eragrostis australasica* tend to be small and patchy rather than large and continuous. The species commonly occurs in depressions within the general matrix of *Atriplex vesicaria* or *Maireana aphylla* and these areas have been mapped as composite units (11/13 and 21/13). Much of the Canegrass community was not mapped due to its patchiness and relatively small extent.

Map unit 16: *Callitris* Mixed Woodland

Structure: woodland – low open woodland #; woodland – isolated clumps ##

Main species: *Callitris glaucophylla* (White Cypress Pine). *Callitris gracilis* subsp. *murrayensis* (Murray Cypress Pine) may replace *Callitris glaucophylla* on sandhills and ridges adjacent to the Murray River on the Deniliquin–Bendigo map.

Associated species: *Hakea leucoptera, Hakea tephrosperma, Alectryon oleifolius* subsp. *canescens*, occasional *Alectryon oleifolius* subsp. *elongatus, Acacia melvillei, Geijera parviflora, Allocasuarina luehmannii, Acacia oswaldii, Acacia homalophylla, Pittosporum phylliraeoides, Casuarina pauper, Eremophila longifolia, Dodonaea viscosa* subsp. *angustissima, Senna artemisioides* subsp. *petiolaris, Maireana pyramidata, Acacia victoriae* (B), *Eucalyptus populnea* subsp. *bimbil* (B), *Eucalyptus intertexta* (B), *Acacia brachybotrya* (D), *Eucalyptus melliodora* (D).

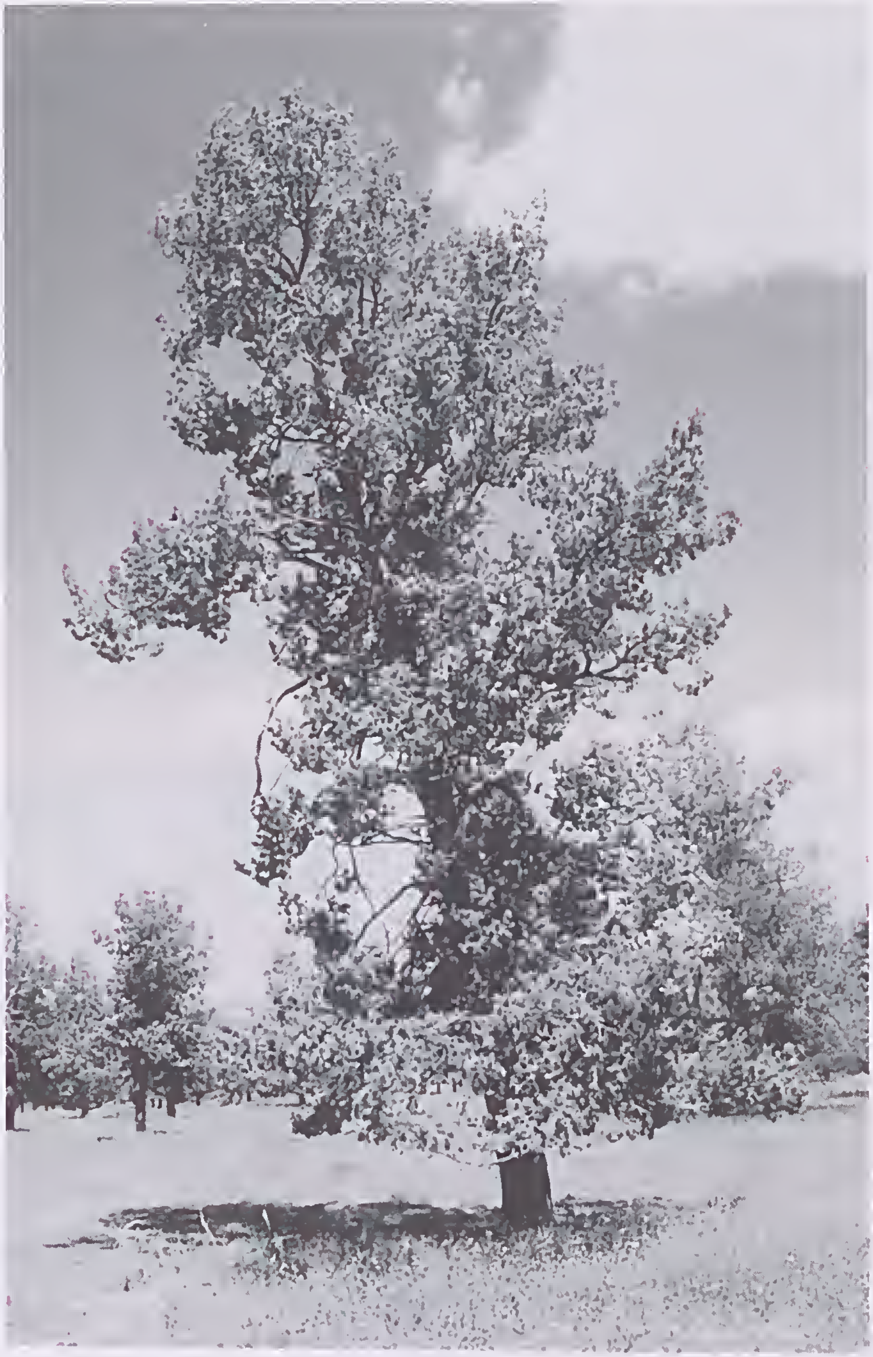

Figure 18. *Callitris glaucophylla* mixed woodland (community 16), north of Gunbar along McKinley Road, in mid-spring.

Landform: Raised sandy areas such as low linear dunes, sandhills, ridges and foot-slopes of rocky outcrops. Old stream beds and levee banks of prior streams and source-bordering dunes formed with the redeposition of prior stream material by wind action (Butler *et al.* 1973). The remnant woodland occupying the major prior streams has been mapped as a separate map unit (see Community 27).

Soils: Coarse-textured red and brown earths such as sandy-loams and loams.

Occurrence: Isolated sandhills with *Callitris* Mixed Woodland occur throughout the mapped area (Fig. 18). Source-bordering dunes associated with prior streams and generally running in an east-west direction occur in the south of the mapped area, notably from west of Booroorban, through the Tchelery Woolsheds area to just north of Moulamein. Continuous, elevated sandridges also occur north of Conargo and Wanganella. Large areas of *Callitris glaucophylla* occur in Booroorban, Steam Plains, Puckawidgee, Edgar and Tholobin State Forests and on the properties 'Oolambeyan', 'Gum Creek', 'Steam Plains' and 'Zara'. Unusual areas of *Callitris glaucophylla* with an *Atriplex nummularia* understorey occur on 'Steam Plains' and 'Zara' properties.

Undulating country with remnant *Callitris glaucophylla* is also seen south-west to south-east of Deniliquin in primarily agricultural land, often associated with remnant Grey Box and Bulloak woodland (Community 25). *Eucalyptus melliodora*, Yellow Box, is associated with *Callitris glaucophylla* on shallow to deep sandy soils in this area, with Cypress Pine dominating on the sandhills (Moore 1953). *Callitris gracilis* subsp. *murrayensis* may replace *Callitris glaucophylla* on the sandhills and elevated plains adjacent to the Murray River (Fig. 19) and hybrids of these two species may occur. Dense stands of *Callitris glaucophylla* occur within the mallee, Belah–Rosewood and *Casuarina pauper*/*Casuarina cristata* intergrading population, along the eastern edge of the Booligal map. Rocky outcrops seen further north support a different Cypress Pine community, described under map unit 29.

Condition: Severe rabbit infestation and scalding; many areas cleared; trees generally thinned and pine selectively logged in state forests; areas of woody shrubs present; few areas with intact shrubby understoreys; understoreys generally degraded to annual grasslands; little regeneration due to grazing stock and rabbits; areas in the south largely cleared and developed for irrigation; dunes of Murray Cypress Pine within River Red Gum forests of the Murray River floodplain largely cleared.

Notes: Mixed woodland, dominated by *Callitris glaucophylla*, extends from Queensland, throughout the slopes and plains of New South Wales, to Victoria. Associated species vary throughout its range. It occurs throughout the Hay Plain but is seen in its greatest density further east.

This vegetation community shows the most variability of all those sampled. Trees may be widely scattered or may form more or less monospecific groves. *Callitris glaucophylla* in particular tends to occur in large stands with other species scattered or in groves in between. Grove-forming species include *Alectryon oleifolius*, *Acacia melvillei* and *Acacia homalophylla*. An understorey is rare, but where present may include *Maireana pyramidata* and *Rhagodia spinescens*. Much of the original understorey has been grazed out but it is thought that common understorey shrubs may have included species of *Dodonaea*, *Pimelea*, *Rhagodia*, *Exocarpos* and *Senna* (Noble & Mulham 1980). Generally the ground cover consists of short-lived perennial and annual grasses and herbs, many of them introduced species. The sandy soils are highly prone to wind erosion and degradation by rabbits.

Occasionally *Callitris glaucophylla* may be absent from this community, with the associated trees mentioned above dominating. *Acacia victoriae* is occasionally seen as a dominant on slight rises north of Booligal. On the Darling floodplain further west

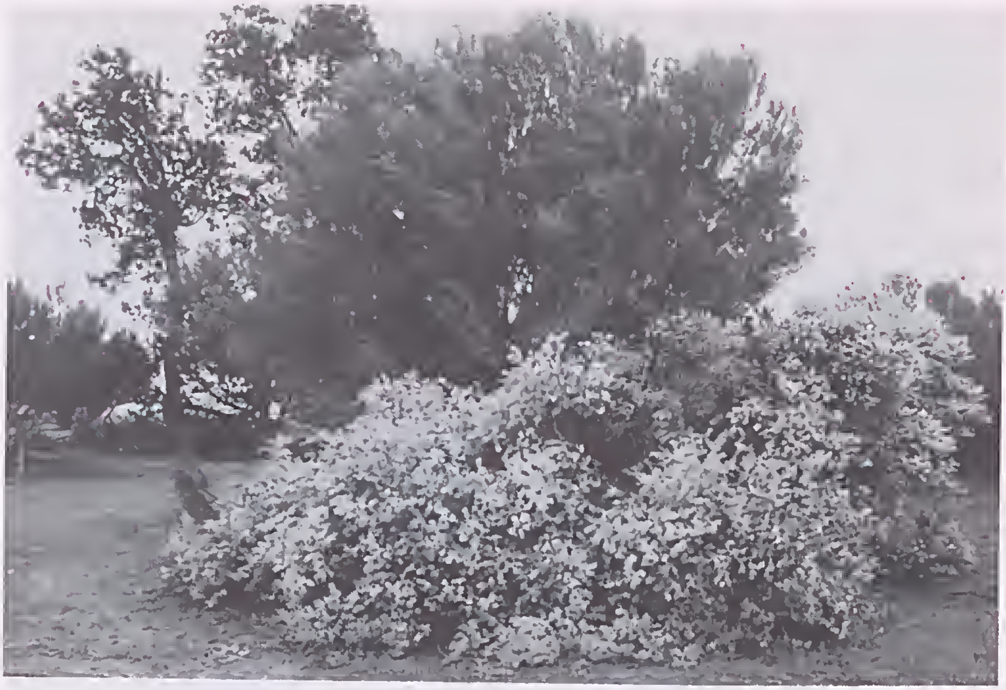

Figure 19. Roadside remnant woodland of *Callitris gracilis* subsp. *murrayensis*, with *Dodonaea viscosa* subsp. *angustissima* and *Acacia brachybotrya* understorey. Sandhill north of Barham within the River Red Gum floodplain of the Murray River, at the end of winter (community 16).

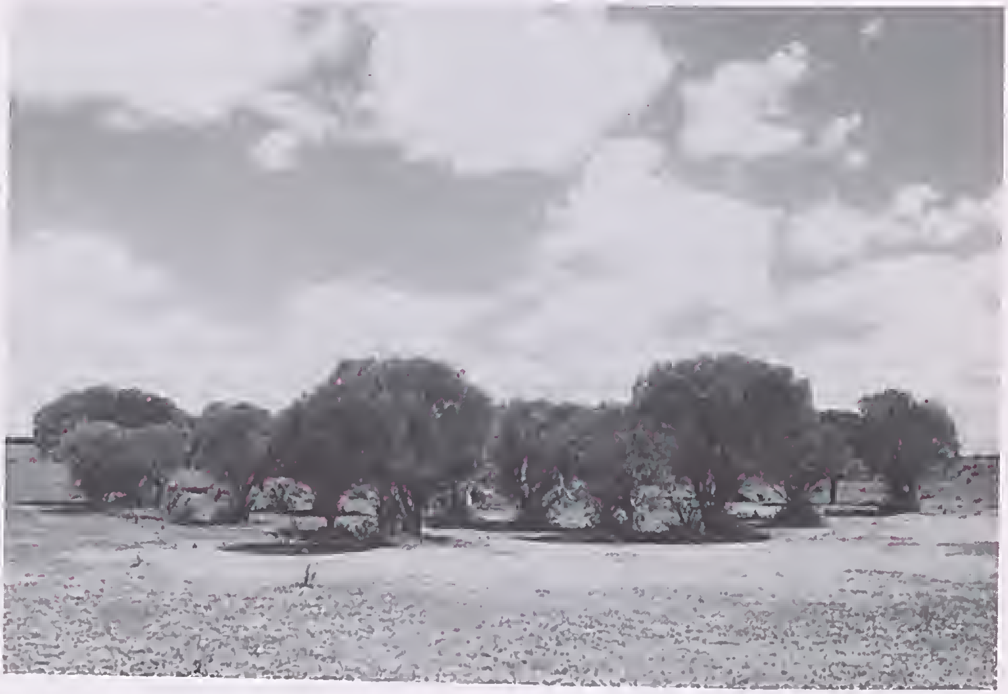

Figure 20. *Acacia melvillei* clump (community 17) on red, duplex soil west of Alma Lake, in mid-spring, with ground cover of *Rhodanthe floribunda* and *Pycnosorus pleiocephalus*.

are many elevated areas of brown solonized soils which are not subject to flooding and carry open or scattered *Acacia victoriae*, sometimes with *Eremophila sturtii* (Turpentine), *Dodonaea* spp. (Hopbushes), Belah and Rosewood (Stannard 1963).

Some species such as *Dodonaea viscosa* subsp. *augustissima*, *Eremophila longifolia* and *Senna* species can form a dense, low, monospecific scrub within this community. As they reduce the grazing potential of the country, they are locally referred to as 'woody weeds'. Large areas occur along the Booroorban–Tchelery road, in Belah–Rosewood country south-west and south-east of Ivanhoe, and in the mallee between Conoble and Roto.

Early explorers remarked on the Cypress Pine during expeditions into western New South Wales: *'On our way to the river, we passed through some dense bushes of casuarinae and cypresses, to the outskirts of the plains through which the Morumbidgee winds'* (Sturt 1833). Once-vast areas of native Cypress Pine between the Murrumbidgee and Lachlan were described by a councillor in 1877 as *'... one magnificent pine forest, containing very fine trees and growing amongst them young trees which absolutely denuded the country of grass, but which, if encouraged, would have formed one of the most magnificent forests in the World ... it was destroyed lock, stock and barrel ... today nothing but stretches of land without a pine tree on them ...'* (Grant 1989). The greatest destruction of White Cypress Pine occurred between 1880 and 1910, when it was extensively cleared for wheat-growing and ringbarked to provide good grazing lands (Grant 1989). The wood was also utilised for fenceposts and other building materials.

Callitris Mixed Woodland is viewed as being particularly vulnerable in the context of present land use in the area. It is under serious threat from rabbits and stock; even-aged, often old stands of trees are not regenerating due to the grazing out of any seedlings produced. Soil erosion is another problem as the coarse-textured soils are undermined by rabbits and scalded due to lack of a stabilising vegetative cover. This community is not conserved within the mapped area and is considered inadequately so elsewhere.

Map unit 17: *Acacia melvillei* Woodland

Structure: tall shrubland – low woodland #; shrubland to woodland ##

Main species: *Acacia melvillei*

Associated species: *Callitris glaucophylla*, *Acacia homalophylla*, *Acacia oswaldii*, *Alectryon oleifolius* subsp. *canescens*, *Casuarina pauper*.

Landform: Level sandplains, undulating plains and low sandy rises.

Soils: Red-brown clay to sandy loam.

Occurrence: Dense *Acacia melvillei* areas occur between Trida and Wee Elwah in the far north of the Booligal map, north of Gunbar along McKinley Road and north of Moulamein in the south-west. Significant stands were also observed around Ivanhoe, to the north of the mapped area. *Acacia melvillei* forms local communities within *Callitris* Mixed Woodlands (Community 16) of sandy rises and source-bordering dunes throughout the Hay Plain, and within the Belah–Rosewood country of the north-west (Fig. 20).

Condition: Severe to moderate scalding and rabbit infestation; many areas cleared; areas of woody shrubs present.

Notes: This community is generally small in extent or forms localised stands in Belah–Rosewood and *Callitris* Mixed Woodlands. Several larger homogeneous areas have

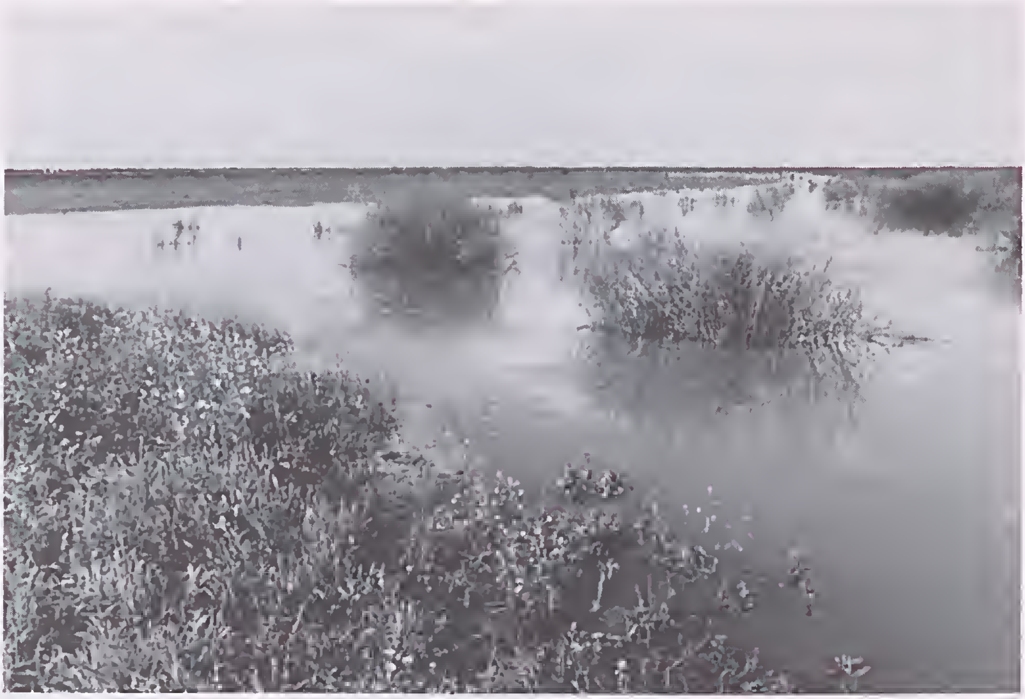

Figure 21. *Muehlenbeckia florulenta* in Fiddlers Creek south of Maude, with herbaceous banks of *Brassica rapa* subsp. *silvestris*; (community 18); early spring.

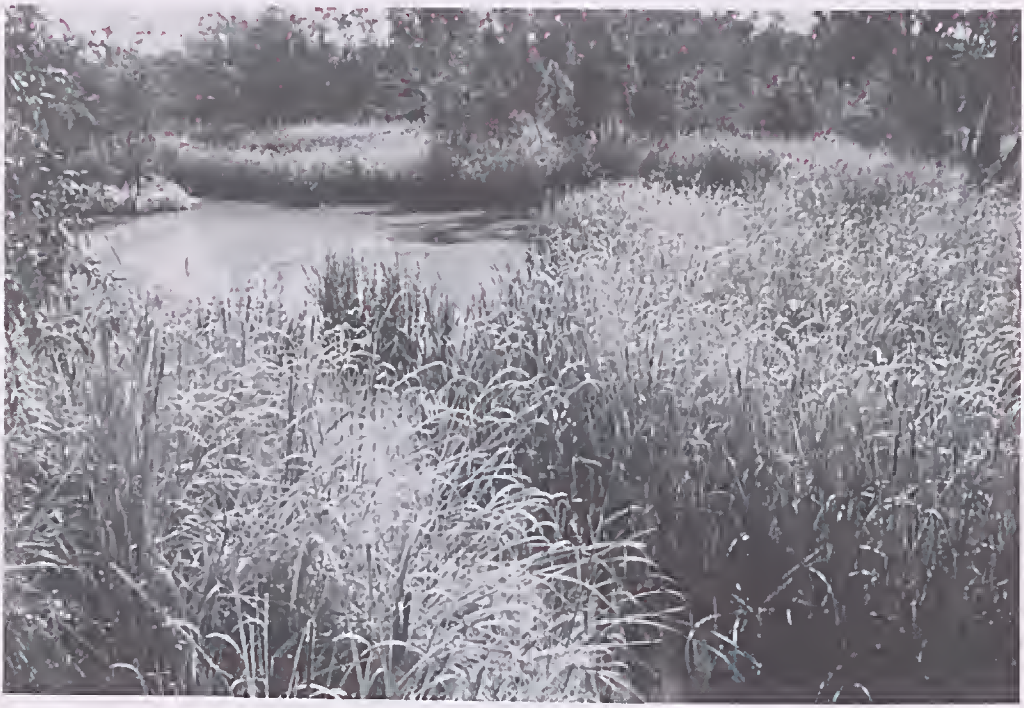

Figure 22. *Typha orientalis* and *Typha domingensis* reed-beds in the Lachlan River, south of Oxley, at the end of autumn.

been mapped. *Acacia melvillei* is often mistaken for the very similar species *Acacia homalophylla* which appears to be more common within other communities rather than as a dominant. The two species differ in the number and arrangement of flower heads in the inflorescence (Harden 1990–92). The populations of *Acacia melvillei* around Ivanhoe are cut for domestic firewood (Semple & Eldridge 1989).

Map unit 18: Lignum and *Chenopodium nitrariaceum*

Structure: low shrubland – open scrub #; open – closed shrubland ##

Main species: *Muehlenbeckia florulenta* (Lignum), *Chenopodium nitrariaceum* (Nitre Goosefoot).

Associated Species: *Eragrostis australasica, Sclerolaena muricata, Juncus flavidus, Juncus radula* and other *Juncus* spp., *Senecio cunninghamii* var. *cunninghamii, Rumex tenax, *Rumex crispus, Atriplex suberecta.*

Species occurring in wetter areas include *Eleocharis acuta, *Alopecurus geniculatus, Marsilea drummondii* and *Limosella australis.*

Landform: Intermittently flooded channels, depressions, river-flats and swamps. Flooding is relatively infrequent, but often prolonged.

Soils: Heavy grey cracking clays.

Occurrence: This community occurs throughout the mapped region, in bands adjacent to major creeks and rivers and in low-lying swampy areas (Fig. 21), particularly north of Booligal and adjacent to the Murrumbidgee and Lachlan Rivers.

Condition: Large areas cleared for irrigation and grazing; many areas degraded to annual grasslands with *Sclerolaena* spp. (copperburrs); some cropping of depressions and lake beds cropped; some weed infestation.

Notes: *Chenopodium nitrariaceum* exceeds Lignum as the dominant species in this community in occasionally inundated areas with less restricted drainage. It is usually seen forming an understorey to *Eucalyptus largiflorens* and often extends out onto the floodplain beyond the woodland zone to form dense shrublands. It is also common in dry lakes and infrequently flooded depressions. *Muehlenbeckia florulenta* withstands relatively infrequent but more prolonged flooding and may form a dense, almost impenetrable scrub (Semple 1990). It favours channelled plains and depressions with impeded drainage but nearly always occurs with *Chenopodium nitrariaceum.*

Lignum swamp areas are often used for cattle grazing and much has been burned or cleared to promote annual herb and grass growth for feed (Semple 1990). This practice is particularly common in areas adjacent to the Murrumbidgee river west of Hay. This community has also been cleared for irrigation in the Deniliquin region.

Lignum areas provide important wildlife habitat, particularly for waterbirds (Semple 1990). A small area of *Eucalyptus camaldulensis, Eucalyptus largiflorens* and *Muehlenbeckia florulenta* (437 ha) is protected in Goonawarra Nature Reserve, south-west of Booligal on the Lachlan River.

Map unit 19: Old Man Saltbush

Structure: low – low open shrubland #; chenopod shrubland – open chenopod shrubland ##

Main species: *Atriplex nummularia* (Old Man Saltbush)

Associated Species: *Rhagodia spinescens, Atriplex vesicaria, Enchylaena tomentosa, Einadia nutans, Eucalyptus largiflorens, Sclerostegia tenuis*, other *Atriplex* spp.

Landform: Level to depressed plains, low-lying areas and depressions.

Soils: Grey, self-mulching, cracking clays to red duplex soils with grey and brown clays. *Atriplex nummularia* grows on a wide range of soil types and at all levels of the plain (Cunningham *et al.* 1981).

Occurrence: This community occurs throughout the Hay Plain with a patchy distribution. Remnant areas occur around One Tree south of Oxley and west of Booligal. It is found in dry lakes in the north-west of the Booligal map, particularly south of Ivanhoe. Black Box woodlands with an understorey of *Atriplex nummularia* occur between Moulamein and Wanganella, with a particularly dense stand seen on 'Bundy'. This association is often found throughout the mapped area (Fig. 17). *Atriplex nummularia* was once a dominant understorey species to *Acacia pendula* (Beadle 1948, Moore 1953) but this association no longer exists within the mapped area.

Condition: Largely cleared; moderately to heavily grazed with shrubs thinned; some scalding in open areas; little regeneration due to grazing stock, rabbits, goats and kangaroos; some weed and copperburr (*Sclerolaena* spp.) infestation.

Notes: *Atriplex nummularia* was once one of the dominant perennial saltbush species on the Hay Plain (Moore 1953, Leigh & Wilson 1970, Leigh & Mulham 1965). Both *Atriplex vesicaria* and *Atriplex nummularia* were far more abundant before the commencement of pastoral activity in the area but their relative dominance is unknown due to the lack of old records and data. It is believed that both species grew so densely on areas of the Plain as to exclude any other perennial species (Beadle 1948). Evidence suggests that *Atriplex nummularia* was the more common species in the far south-east of the South Western Plains botanical region (Moore 1953).

The mapped areas of Old Man Saltbush are remnants of once-extensive stands that have been subjected to grazing pressure, rabbit-disturbance and clearing. The shrub is palatable to stock and rabbits and recovers well after intermittent grazing, however constant defoliation under heavy grazing pressure is detrimental (Cunningham *et al.* 1981). It was considered an important fodder species before it was grazed out (Beadle 1948). Many small remnants occur around homesteads and in small holding paddocks that saw little grazing. The larger remnant areas are delineated on the maps but many smaller patches exist, often consisting of only scattered individuals.

Maireana pyramidata may occur with *Atriplex nummularia* at transition zones where higher country supporting this species grades off to low-lying areas with *Atriplex nummularia*. This is often seen in undulating country such as that around Oxley and 'Wongalea' east of Gunbar.

Map unit 21: Cotton Bush

Structure: low – low open shrubland #; chenopod shrubland – sparse chenopod shrubland ##

Main species: *Maireana aphylla* (Cotton Bush)

Associated Species: *Atriplex vesicaria, Sclerolaena muricata, Sclerolaena tricuspis, Nitraria billardierei, Minuria cunninghamii, Ixiolaena tomentosa, Osteocarpum acropterum* var. *deminuta, Leptorhynchos panaetioides, Atriplex lindleyi, Atriplex pseudocampanulata, Malacocera tricornis, Danthonia caespitosa, Calocephalus sonderi, Sclerolaena bicornis* var. *bicornis, Daucus glochidiatus, *Cotula bipinnata, Rhodanthe corymbiflora, Rhodanthe pygmaea,* *Plantago cunninghamii, Podolepis muelleri, Calotis scabiosifoia* subsp. *scabiosifolia, Brachycome lineariloba.*

Landform: Depressed alluvial plains, usually disturbed.

Soils: Grey to grey-brown clays to clay-loams (Leigh & Mulham 1965).

Occurrence: This community is widespread over the Hay Plain and has proliferated in many areas once dominated by *Atriplex vesicaria* (Fig. 23). The largest continuous stands occur south to south-west of Hay. Dense areas occur within Willandra National Park, north-west of Hillston. *Maireana aphylla* originally occurred with *Atriplex vesicaria* in slightly depressed areas mainly in the east Darling area and excessive grazing has led to its increase with the elimination of *Atriplex vesicaria* over large areas (Beadle 1948).

Condition: Extensive areas degraded to annual grasslands with *Sclerolaena* spp. and *Nitraria billardierei*; weed infestation common; soils often scalded.

Notes: *Maireana aphylla* shrubland is usually grazed or variously disturbed and is considered to be a degraded or disclimax community from Bladder Saltbush shrubland as a result of heavy grazing (Beadle 1948). Shrublands dominated by *Nitraria billardierei, Sclerolaena muricata* and *Sclerolaena tricuspis* indicate greater disturbance. The herbaceous layer within this community consists of short-lived perennial and annual grasses and herbs, many of them introduced. The invasion by exotic pasture species such as **Avena fatua, *Hordeum leporinum, *Lolium perenne, *Phalaris paradoxa, *Phalaris minor, *Bromus madritensis, *Medicago* spp. and **Erodium* spp. has been widespread. These species are indicative of the often disturbed nature of this community.

Maireana aphylla distribution has increased since the *Atriplex vesicaria* dieback of 1977–1983 (Clift *et al.* 1987, Clift *et al.* 1989, Semple 1989). Post-dieback distribution of *Maireana aphylla* has been mapped.

Maireana aphylla and *Nitraria billardierei* tend to occur on slightly depressed areas of the Plain as they are more flood-tolerant than *Atriplex vesicaria* (Beadle 1948). *Maireana aphylla* is often associated with medium to heavy scalding and occasional individuals or patches of remnant *Atriplex vesicaria* may be seen. Shrub cover can vary considerably in this community, ranging from dense monospecific stands to scattered individuals within a matrix comprising annual and short-lived perennial grasses.

Map unit 22: Dillon Bush

Structure: low – low open shrubland #; shrubland – sparse shrubland ##

Main species: *Nitraria billardierei* (Dillon Bush)

Associated Species: *Maireana aphylla, Sclerolaena muricata, Sclerolaena tricuspis.* This community occupies disturbed areas and usually comprises a high proportion of introduced and annual species. Other associated species vary depending on the composition of the original vegetation.

Landform: Disturbed low-lying alluvial plains, dry lakebeds.

Soils: Grey to grey-brown clay and loam soils, often saline (Cunningham *et al.* 1981).

Occurrence: *Nitraria billardierei* tends to occur in dense continuous stands in areas of high grazing pressure, particularly adjacent to riverine and box woodlands, and in previously cropped areas. Its distribution has increased markedly with the changed land use in the area since European settlement. Severe overgrazing of the original

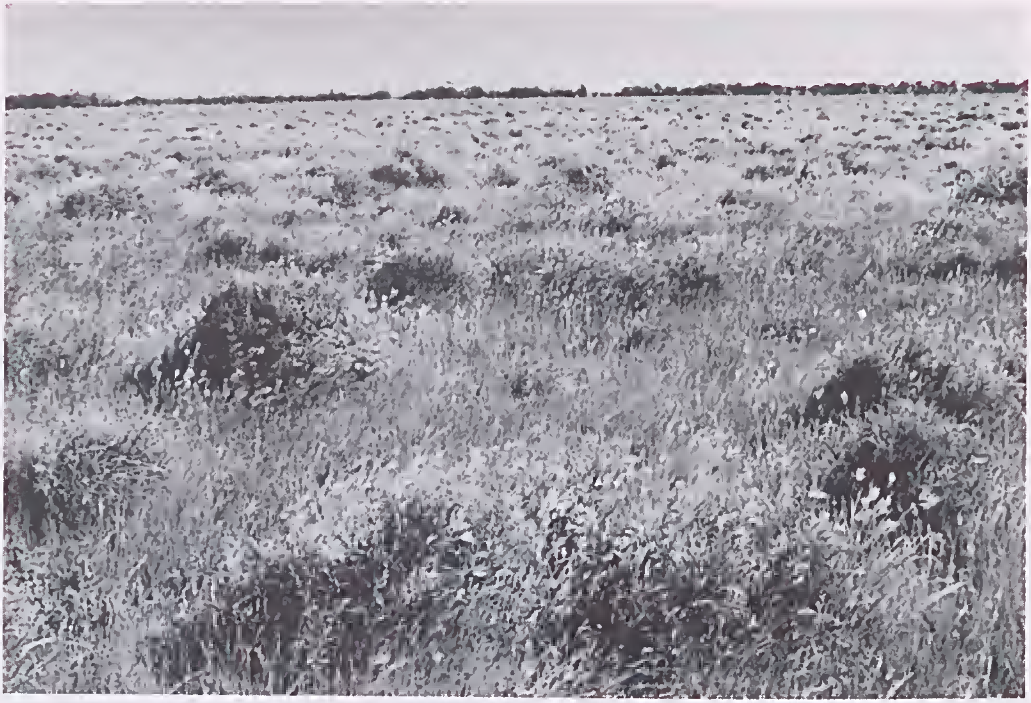

Figure 23. *Maireana aphylla* shrubland (community 21) north-west of Deniliquin, with ground cover of *Bromus diandrus* in early spring.

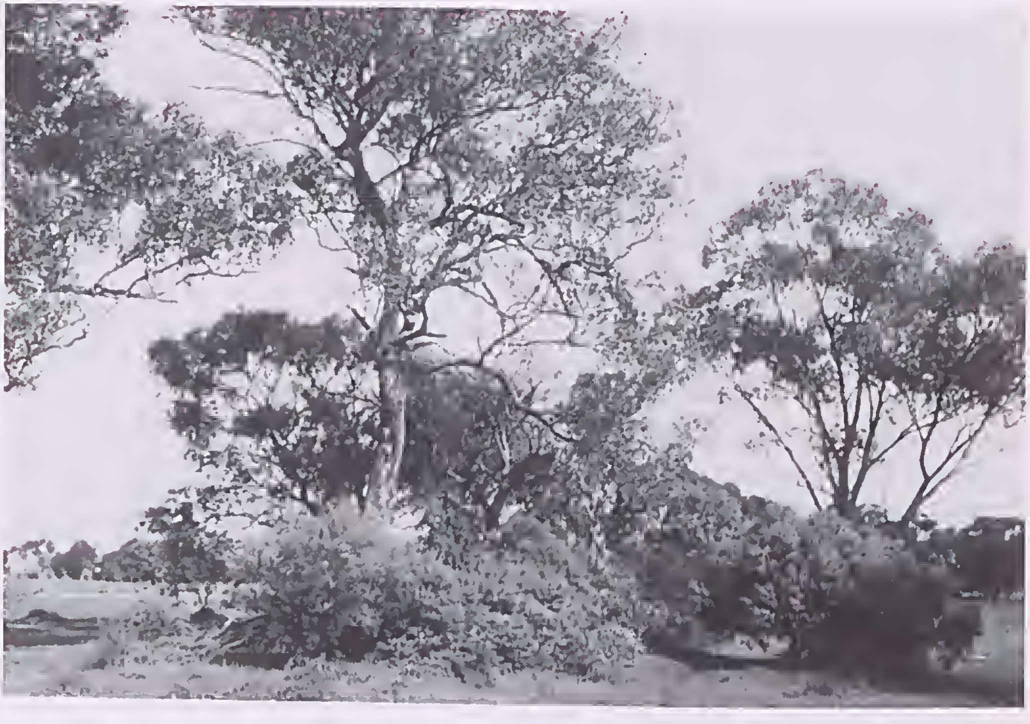

Figure 24. Roadside remnant *Eucalyptus microcarpa* (community 24) with *Acacia hakeoides* understorey; Mooney Swamp Road, north-east of Deniliquin, at the end of winter.

chenopod species has resulted in the establishment of Dillon Bush in areas once occupied by *Atriplex vesicaria* and *Atriplex nummularia* (Noble & Whalley 1978). Dillon Bush commonly occurs in lower densities within other shrubland and woodland communities. The species provides good harbour for rabbits due to its thick and spreading habit.

Map unit 23: Great Cumbung Swamp

This community was not sampled in the current survey and information has been taken from various sources and mapped with reference to Pressey *et al.* 1984.

Structure: closed – open herbland/grassland #; closed – open grassland/rushland/ forbland ##

Main species: *Phragmites australis* (Common Reed), *Senecio cunninghamii* var. *cunninghamii* (Bushy Groundsel), *Typha orientalis* and *Typha domingensis* (Cumbung or Bulrush).

Associated Species: **Hordeum leporinum, *Polypogon monspeliensis, *Cirsium vulgare, Pratia concolor, Marsilea drummondii, Juncus flavidus, Centipeda cunninghamii, Persicaria decipiens, Paspalum distichum, *Cotula coronopifolia, Eucalyptus camaldulensis, *Ranunculus sceleratus, Cyperus gymnocaulos, Vallisneria gigantea, *Juncus articulatus, Potamogeton crispus.*

Landform: Regularly inundated swamp at the confluence of the Murrumbidgee and Lachlan Rivers, with some areas of semi-permanent open water.

Soils: Heavy grey clays.

Occurrence: The Great Cumbung Swamp occurs at the far western edge of the Hay sheet. Areas of *Phragmites australis* and *Typha* spp. may occur throughout the mapped area, wherever there is relatively still, semi-permanent water or in periodically flooded situations. *Typha* spp. are particularly common in marshes, billabongs and creeks with River Red Gum forest or fringing Black Box woodland (Fig. 22).

Condition: River regulation resulting in a reduction in range of the community; some weed infestation.

Notes: Distinct zonation of the main species occurs in the Great Cumbung Swamp. *Typha* species dominate the areas of semi-permanent water with *Phragmites australis* occurring from approximately 0.3 m above the upper *Typha* limit at the periodically flooded lower banks (Pressey *et al.* 1984). *Senecio cunninghamii* var. *cunninghamii* occurs in a broad zone above, and overlapping with *Phragmites australis*. The hydrology of the swamp is influenced by the diversion of water for irrigation from the Murrumbidgee. Natural flooding occurs mainly in spring and summer. The extensive patches of semi-permanent water in the Great Cumbung Swamp can completely dry up during drought periods (Pressey *et al.* 1984).

The Lachlan–Murrumbidgee confluence encompasses other wetland communities besides the Great Cumbung Swamp. It also includes areas of *Eucalyptus largiflorens* and *Eucalyptus camaldulensis*, marshes and lakes on the main floodplain of the Murrumbidgee, and an extensive channelled Lignum area associated with the Murrumbidgee (Pressey 1988). The latter two areas are influenced by water diversions from Redbank and Maude Weirs respectively.

Map unit 24: Grey Box Woodland

Structure: low woodland – woodland #; open woodland – woodland ## (*Eucalyptus microcarpa* occasionally reaches open forest proportions # and ##)

Main species: *Eucalyptus microcarpa* (Grey Box) (D)

Associated Species: *Allocasuarina luehmannii* (Bulloak), *Eucalyptus melliodora* (Yellow Box) (D), *Acacia hakeoides, Acacia brachybotrya* (D), *Acacia acinacea* (D), *Callitris glaucophylla, Senna artemisioides* subsp. *zygophylla, Senna artemisioides* subsp. *filifolia* and *Senna artemisioides* nothosubsp. *coriacea, Acacia rigens* (D).

Landform: Level to undulating plains, elevated flats and rises adjacent to the Murray and Edward–Wakool river systems.

Soils: Red-brown earths and heavy clay to loamy alluvial soils (Cunningham *et al.* 1981). Deeper sandy soils to the south-east of Deniliquin (Moore 1953).

Occurrence: *Eucalyptus microcarpa* woodland occurs in the far south of the Hay Plain, restricted to the Deniliquin map sheet (Fig. 24). It is seen from east to south-west of Deniliquin, extending down to the Murray River and has its northern limit on the Plain within the Edward–Wakool river system, where it forms open forest within River Red Gum communities. *Eucalyptus microcarpa* gradually replaces *Eucalyptus largiflorens* south of Deniliquin where it occurs on higher loam soils in association with *Allocasuarina luehmannii* (Bulloak) and *Eucalyptus melliodora* (Yellow Box). Remnant areas occur just north-east of Deniliquin.

Condition: Largely cleared and developed for irrigation; remnant areas prone to weed and rabbit infestation; few remnants with shrubby understoreys intact; little regeneration due to clearing, stock and rabbits.

Notes: *Eucalyptus microcarpa* has been extensively cleared and thinned for both grazing and cropping. Around Deniliquin, this species and *Allocasuarina luehmannii* have been reduced to remnant patches of scattered trees within irrigated agricultural land. Very few areas exist with an intact shrubby understorey, most of these being roadside remnants. Small remnant stands with *Acacia* and *Senna* understoreys exist around Mathoura, north-east of Deniliquin and along Lower Thule Road east of Barham. Taller *Eucalyptus microcarpa* forest occurs with *Eucalyptus melliodora* on the heavy clays within riparian forests. In Werai State Forest north-west of Deniliquin, Aboriginal people cut the bark from the tall *Eucalyptus microcarpa* trees for canoes.

Acacia oswaldii, Acacia salicina, Acacia rigens and *Eremophila longifolia* have been listed by other authors as associated species (Semple 1990). In the present survey, small areas with *Acacia rigens* and *Acacia oswaldii* were seen along the railway at Burraboi north-west of Deniliquin and along Lower Thule Road east of Barham. *Acacia salicina* was not observed as an associate species.

Beadle mentions already in 1948 that few virgin stands of the woodland exist but that tree densities were once high, having been cleared for wheat growing or thinned for sheep grazing. Shrub species were already inconspicuous then but included *Acacia oswaldii, Acacia deanei, Acacia hakeoides, Acacia rigens, Hakea leucoptera, Pittosporum phylliraeoides, Eremophila longifolia* and *Dodonaea viscosa* subsp. *spatulata*. He suggests the herbaceous stratum was probably discontinuous and comprised shade-loving species like *Wahlenbergia gracilis* and *Carex inversa* and perennial grasses such as *Danthonia* spp. (Beadle 1948).

Callitris glaucophylla (Community 16) on sandy to loam rises occurs as a local community within *Eucalyptus microcarpa* woodland east to south-west of Deniliquin. *Allocasuarina luehmannii* and *Callitris glaucophylla* are common associates, occurring on higher ground above the level of the *Eucalyptus microcarpa*. *Eucalyptus melliodora* is less abundant in this undulating country, observed more often with Grey Box in riparian situations.

Beadle (1948) included *Eucalyptus microcarpa* in his concept of *Eucalyptus woollsiana*, describing the association as a tall woodland with an eastern distribution from around Condobolin to south of Deniliquin. Grey Box is described as occurring either in pure stands or in association with *Callitris glaucophylla* or *Eucalyptus populnea* subsp. *bimbil* (Bimble Box), a community which is presently more common east of the Hay Plain. The soils are red-brown earths, sometimes a sandy loam but usually a loam or clay-loam overlying a clayey subsurface soil with lime occurring in varying quantities throughout the profile. Yellow Box is mentioned as an associated species while *Callitris glaucophylla* is present as a lower tree layer. *Allocasuarina luehmannii* forms local societies within Grey Box (Beadle 1948). The Grey Box Woodland of the current survey also appears to be synonymous with the *Eucalyptus woollsiana* and *Callitris glaucophylla* association identified by Moore (1953) where *Allocasuarina luehmannii* is described as a subsidiary species in the tree stratum.

Map unit 25: *Acacia pendula* Woodland

Structure: low – low open woodland #; open woodland – woodland ##

Main species: *Acacia pendula* (Myall or Boree)

Associated Species: *Rhagodia spinescens*, *Atriplex nummularia* (largely cleared), *Danthonia caespitosa*, *Maireana aphylla*, annual *Atriplex* spp., annual and short-lived perennial grasses, **Medicago* spp., *Enchylaena tomentosa*, *Atriplex semibaccata*, *Maireana decalvans*, *Stipa nodosa*.

Amyema quandang subsp. *quandang* commonly occurs as a parasite on *Acacia pendula* but the mistletoe rarely kills the host (Beadle 1981).

Other common associate species which may vary seasonally or with grazing pressure include *Alternanthera denticulata*, *Centipeda cunninghamii*, *Sida* spp., *Rhodanthe corymbiflora*, *Maireana pentagona*, *Sclerolaena stelligera*, *Erodium* spp., *Myriocephalus rhizocephalus* subsp. *rhizocephalus*, **Cotula bipinnata*, *Vittadinia cuneata* var. *cuneata*, *Lepidium pseudohyssopifolium*, *Enteropogon acicularis*, *Ranunculus* spp.

Landform: Level to depressed plains. Adjacent to streams or in depressions in grasslands (Beadle 1981).

Soils: Grey and brown clays and more rarely on red-brown earths (Beadle 1981, Semple 1990).

Occurrence: *Acacia pendula* occurs mainly in the east of the Hay Plain and is seen here at the western limit of its range (Fig.25). The densest stands occur east of Hay along the Gum Creek–Conargo Road, along Wrights Lane south-east of Gunbar, east to north-east of Conargo and south of Hillston along McKinley Road. Isolated groves and scattered trees occur within *Danthonia caespitosa* (Community 26), *Eucalyptus largiflorens* (Community 2) and lower areas within *Casuarina pauper*/*Casuarina cristata*-intergrade woodland (Community 28) in the eastern sector of the Plain. Roadside remnants exist in agricultural country around Deniliquin and Hillston.

Condition: Widely cleared or thinned with extensive areas degraded to annual grasslands; moderate scalding and rabbit infestation; some areas of woody shrubs present; weeds common; few areas with shrubby understoreys; understoreys generally degraded to annual grasslands; little regeneration due to grazing.

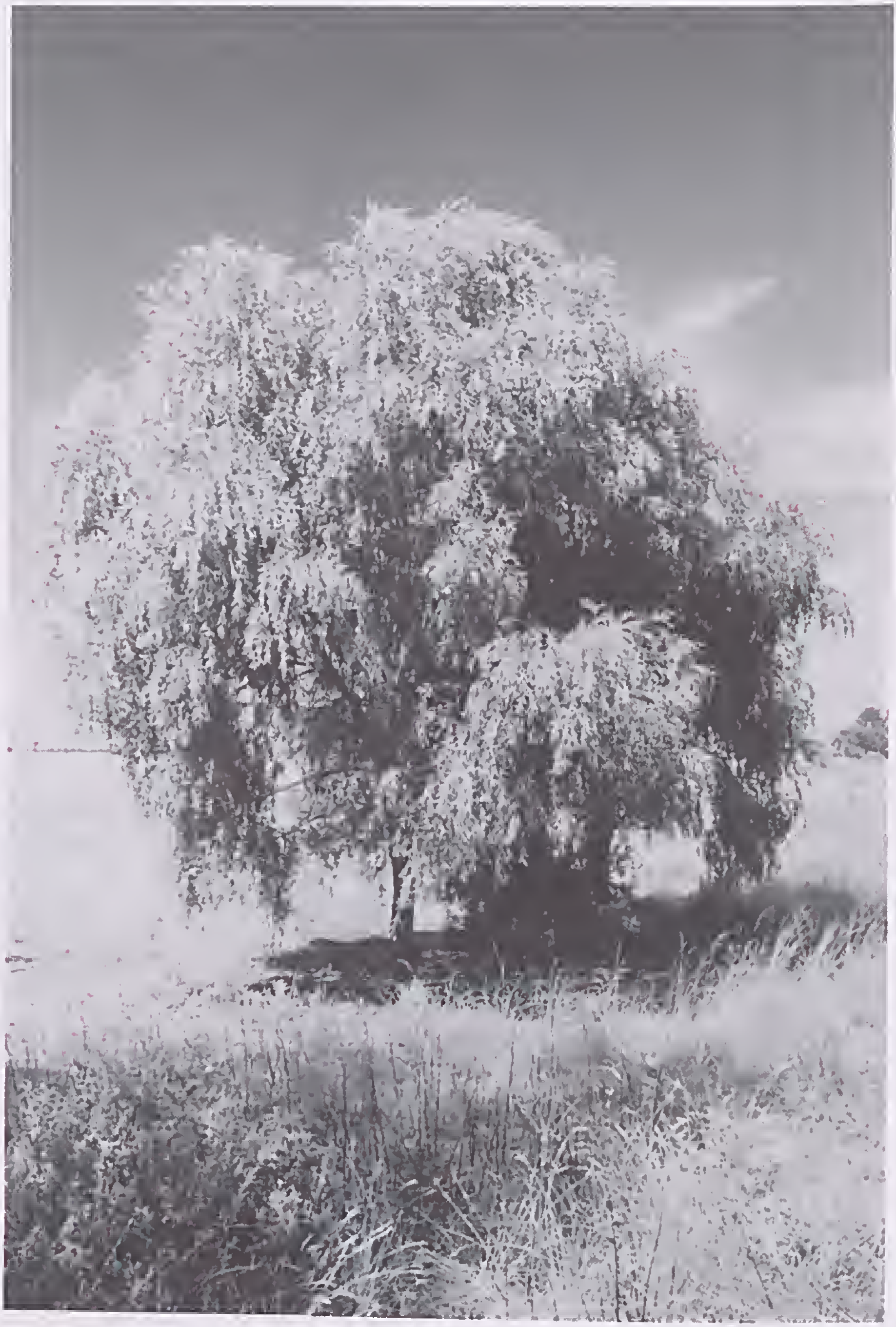

Figure 25. *Acacia pendula* open woodland at the end of summer (community 25), with *Rhagodia spinescens* and grassy understorey; Jerilderie Road, south-east of Hay.

Notes: Widespread clearing of *Acacia pendula* for cropping, fodder and timber has resulted in a patchy remnant distribution. It commonly occurs with a very open structure and a herbaceous understorey, mostly comprising **Medicago* spp. and grasses such as *Danthonia caespitosa, Enteropogon acicularis, *Lolium perenne, *Hordeum leporinum, *Vulpia myuros* and **Bromus madritensis*. A shrubby understorey is rare or lacking. The original *Atriplex nummularia* understorey has been largely cleared. Moore (1953) noted remnants as existing in the Jerilderie area. *Atriplex vesicaria* and *Maireana aphylla* are also listed as original understorey components with the latter persisting over the two species (Beadle 1981). There are few tree associates but where present may include *Acacia salicina* and *Acacia oswaldii* (Beadle 1981).

The disappearance of the *Acacia pendula-Atriplex nummularia* alliance is attributed mainly to heavy sheep grazing followed by the severe drought of 1875 to 1877 (Moore 1953). *Acacia pendula* was felled for stock feed and regeneration was prevented by stock and rabbit grazing. The *Danthonia caespitosa* grassland areas are believed to be disclimax communities which once carried the *Acacia pendula–Atriplex nummularia* association (Beadle 1948, Moore 1953). Perennial grasslands still support a wide range of native plants including rare species such as *Swainsona plagiotropis* (see Table 5). Scattered *Acacia pendula* occurs within the mapped *Danthonia caespitosa* grasslands (see Community 26) lending support to this disclimax theory. None of this association exists within the mapped area today, with the only known stands remaining on two merino properties west of Jerilderie; 'Coonong' and 'Coree' (Moore 1953).

Acacia pendula woodland is a vulnerable vegetation type and is not represented in any conservation reserve in south-western New South Wales (Brickhill 1985). Unlike most *Acacia* species, *Acacia pendula* fruits and sets seed sparingly and seed germination is poor (Beadle 1981). The foliage is readily eaten by stock and any seedlings produced are prone to grazing or trampling. Rabbits may also undermine the root systems in lighter clay soils.

Map unit 26: White-top Grassland

Structure: tussock grassland – open tussock grassland #; grassland – open grassland ##

Main species: *Danthonia caespitosa* (White-top or Ringed Wallaby Grass) predominantly, but there is usually a *Danthonia eriantha* component of about 10 per cent (S. Jacobs, Royal Botanic Gardens, pers. comm.).

Associated Species: *Chloris truncata* (Windmill Grass), *Enteropogon acicularis, Sporobolus caroli, Bromus arenarius, Stipa nodosa, *Hordeum leporinum, *Lolium perenne, *Lolium rigidum, *Avena fatua, *Bromus madritensis, *Vulpia myuros, *Medicago* spp., **Erodium* spp., *Rhodanthe corymbiflora, Sida trichopoda, Sida corrugata, Maireana aphylla* (occasionally).

Landform: Level alluvial plains.

Soils: Grey to brown clays or clay-loams, usually with a compacted surface (Beadle 1948).

Occurrence: This grassland is composed of short-lived perennial and annual grasses and occurs in the east to south-east of the Hay Plain, extending from north-east of Deniliquin to south of Gunbar. The most homogeneous areas are found south-east to north-east of Hay (Fig. 26).

Condition: Moderately to extensively grazed with many areas degraded to annual grasslands.

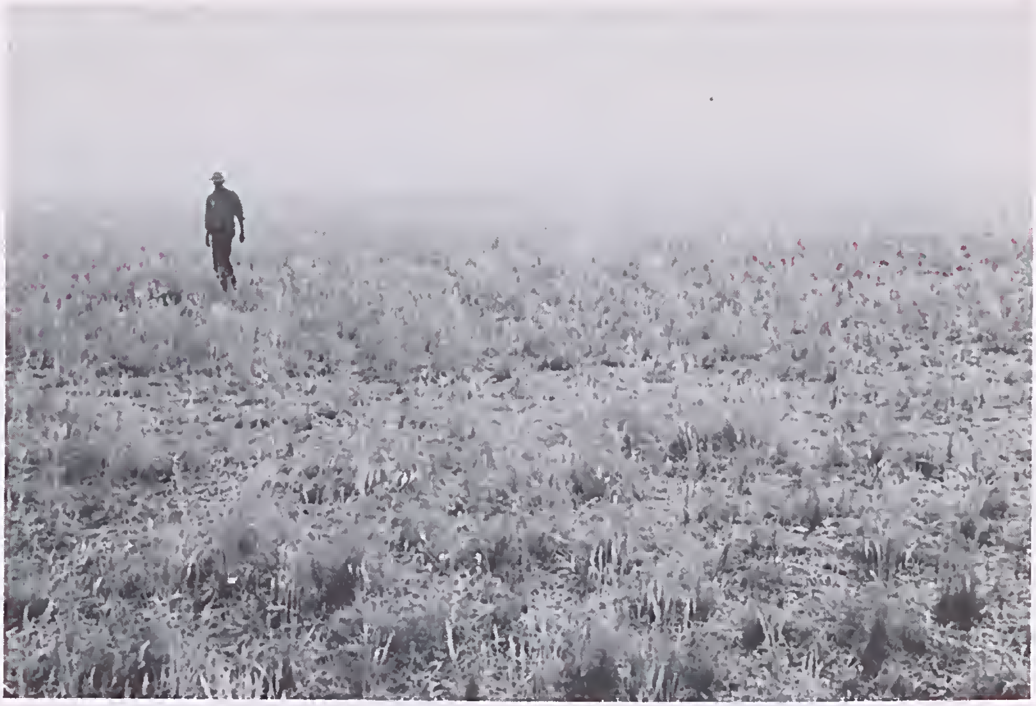

Figure 26. Dried-off grassland of *Danthonia caespitosa* (community 26) at the end of summer, north of Carrathool in the far east of the Hay Plain.

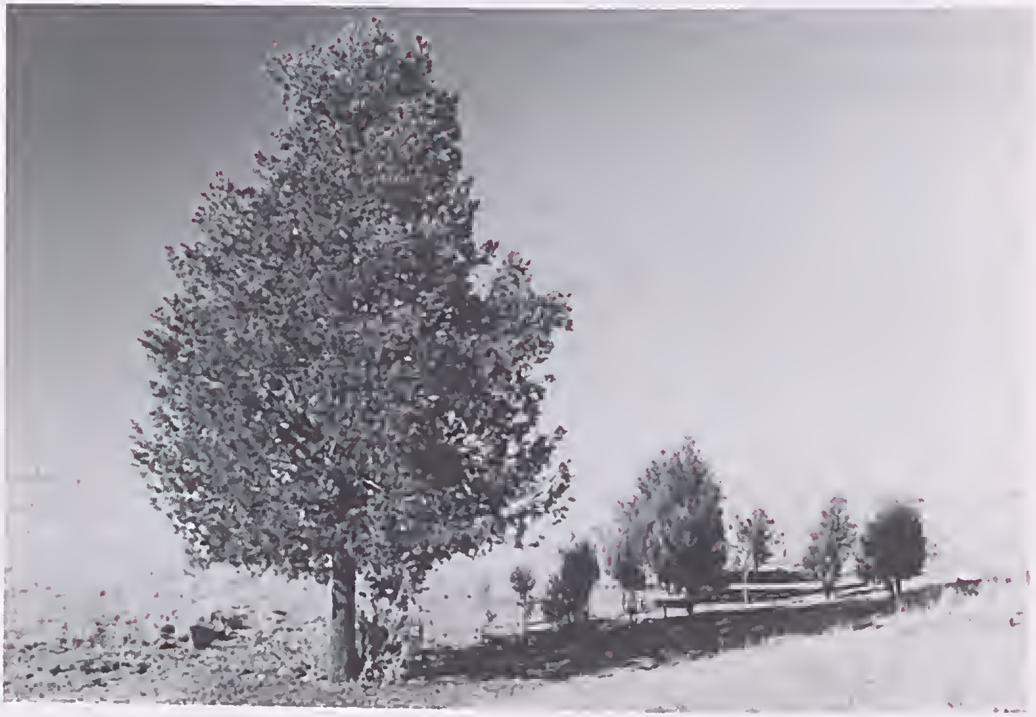

Figure 27. *Callitris glaucophylla* regenerating on prior stream (community 27), within an exclosure on 'Walgrove', south-east of Hay, at the end of summer.

Notes: Previous records and surveys suggest that *Danthonia caespitosa* grassland is a degraded or disclimax community that has developed under heavy grazing from climax communities dominated by *Acacia pendula–Atriplex nummularia* (Moore 1953) or *Atriplex vesicaria* (Beadle 1948). According to Beadle (1948) *Atriplex vesicaria* once occurred in areas now carrying grasslands (*Chloris–Danthonia* association) and *Maireana aphylla*. When the shrub phase is removed by grazing, perennial grasses such as *Danthonia* and *Chloris* remain; they in turn can be grazed out, leaving annual grasses and annual or short-lived spiny-fruited chenopods (S. Jacobs pers. comm.). In a study concentrating on the grasslands around Jerilderie, Narrandera and Urana to the east of the study area, Moore (1953), suggests that these grassland areas once carried *Acacia pendula* and *Atriplex nummularia* with *Atriplex vesicaria*. *Acacia pendula* remnants currently exist in the mapped grasslands, but no *Atriplex nummularia* and little *Atriplex vesicaria*.

Danthonia caespitosa may dominate the ground layer in *Eucalyptus largiflorens*, *Acacia pendula* and other woodland communities. Short-lived perennial and annual grasses dominate the pasture in more disturbed communities with a seasonal composition. Common species include **Hordeum leporinum*, **Lolium perenne*, **Avena fatua* and **Bromus madritensis*. At various times of the year **Medicago* spp., **Erodium* spp. and other herbs (commonly Asteraceae) are a significant component of the ground layer.

Where grazing is not too severe, *Danthonia caespitosa* will seed and recruit regularly (Cunningham *et al.* 1981). The species may be eliminated with heavy, continuous grazing and replaced with *Chloris truncata* and annual grasses. Severe grazing pressure and disturbance can lead to the removal of *Chloris truncata*, resulting in a herbfield or grassland comprising annual species (Beadle 1948).

The grassland areas south-east of Hay were affected by wildfires in November 1990. A large area of *Danthonia caespitosa* grassland was burned and much of it has not regenerated as at October 1992, but has been replaced by other grass and herb species. The grassland distribution prior to the fire has been mapped.

Map unit 27: Prior Stream Remnant Woodland

Structure: low open woodland #; open woodland - isolated trees ##

Main species: *Callitris glaucophylla* (White Cypress Pine), *Hakea leucoptera* (Needlewood), *Hakea tephrosperma* (Hooked Needlewood).

Associated Species: *Pittosporum phylliraeoides*, *Alectryon oleifolius* subsp. *canescens*, occasional *Alectryon oleifolius* subsp. *elongatus*, *Rhagodia spinescens*, *Stipa scabra* subsp. *scabra*, *Aristida behriana*, *Enneapogon nigricans*, **Cucumis myriocarpus*, *Wahlenbergia stricta* subsp. *stricta*.

Landform: Raised beds of prior streams indicated by low, winding sandy ridges on the clay floodplain (Butler *et al.* 1973).

Soils: Gravel, sand and sandy-loam overlying clay (Butler 1950).

Occurrence: Prior streams occur mainly east to south-east of Hay within the mapped area although they are seen more frequently south and west of Griffith (Schumm 1968). Large prior streams run through 'Walgrove' property (Fig. 27), Wrights Lane and Murrumbidgee River Road north-east of Hay. Several are also seen north of Conargo.

Condition: Largely cleared; severe scalding and soil erosion due to rabbit infestation; little regeneration due to grazing stock and rabbits.

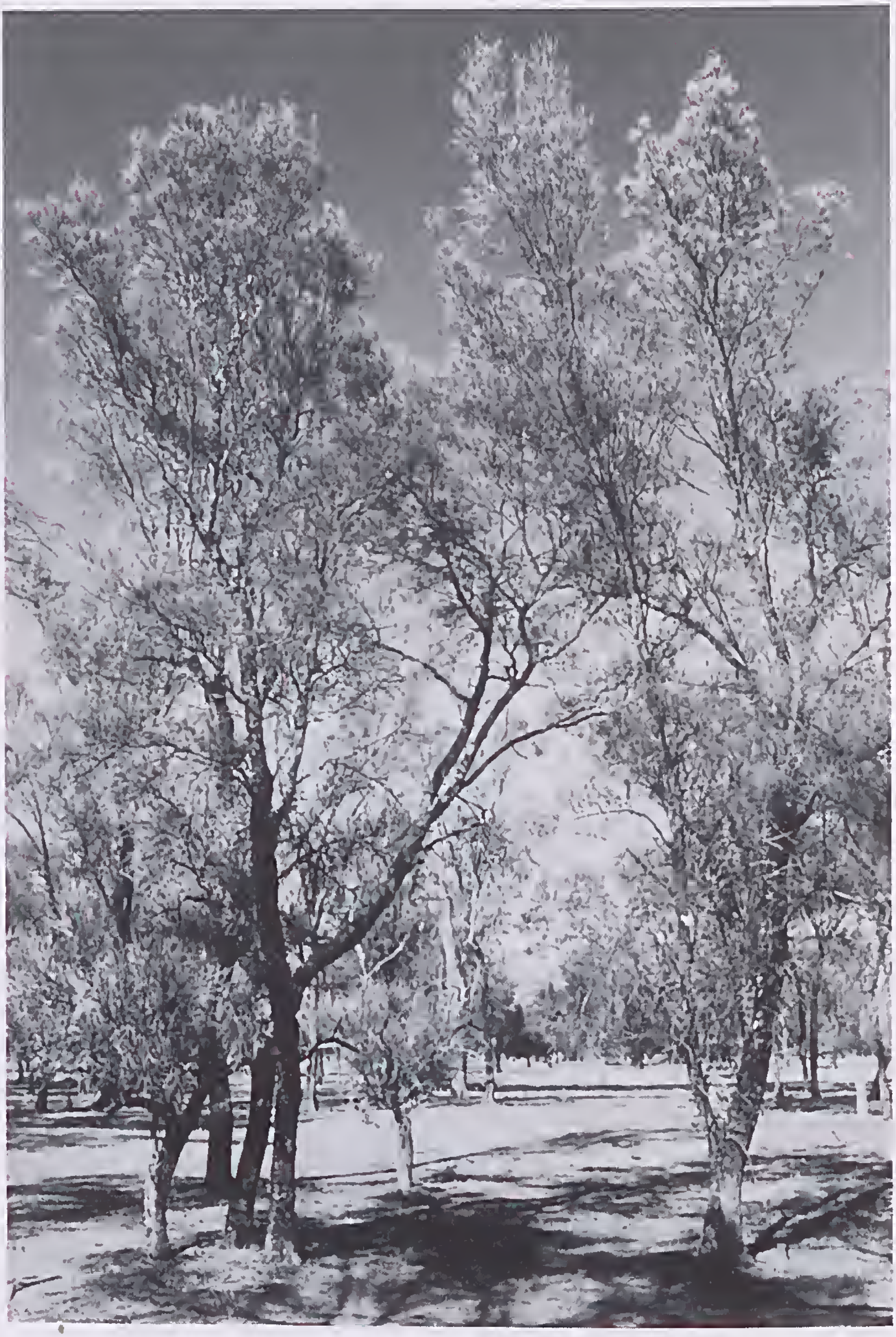

Figure 28. Woodland of *Casuarina pauper*/*Casuarina cristata* intergrades (community 28) with *Apophyllum anomalum* (Warrior Bush) in the left-foreground; north-east of Gunbar in mid-spring.

Notes: This vegetation community is of a very remnant nature, often reduced to just several scattered trees or a small grove. Prior streams are not always obvious on the ground and are usually visible as a line of scattered trees on a low narrow rise with adjacent scalding. Isolated groves of *Hakea* spp. or *Pittosporum phylliraeoides* may also indicate the existence of a prior stream. The stream trace is continuous and well-defined on aerial photos.

As well as *Callitris glaucophylla*, *Hakea* spp. and *Alectryon oleifolius*, prior streams once supported stands of *Acacia homalophylla*, *Casuarina pauper* and *Geijera parviflora* (Semple 1987a).

Prior streams are the last of a series of alluvial systems deposited on the Plain during late Pleistocene times and functional up till Recent times (Butler 1950). They have been mapped to include the elevated stream bed and associated scalded levees. The dunes range in height from 3 to 15 metres (Semple & Eldridge 1989).

Map unit 28: *Casuarina pauper/Casuarina cristata* Intergrading Population

Structure: low woodland – woodland #; open woodland – woodland ##

Main species: *Casuarina pauper/Casuarina cristata* intergrades

Associated Species: *Geijera parviflora* (Wilga), *Exocarpos aphyllus* (Leafless Cherry), *Apophyllum anomalum* (Warrior Bush), *Alectryon oleifolius* subsp. *canescens*, occasional *Alectryon oleifolius* subsp. *elongatus*, *Maireana georgei* (Satiny Bluebush), *Rhagodia spinescens*, *Enchylaena tomentosa*, *Maireana decalvans*, *Maireana pyramidata*, *Atriplex stipitata*, *Sclerolaena birchii*, *Zygophyllum glaucum*.

Landform: Flat to gently undulating plains, largely aeolian.

Soils: Texture-contrast soils of brown to red-brown sandy loam to loam, overlying red to red-brown clays.

Occurrence: This intergrading population occurs in a localised area between Gunbar and Hillston, along the central-eastern edge of the mapped area (Fig. 28). It extends from south-west of Gunbar through to south-west of Hillston. The densest continuous stands occur north of Gunbar on level to slightly undulating plains along McKinley, Booligal, Gunbar and Old Gunbar Roads.

Condition: Many areas cleared but remnants generally dense and with understorey shrubs present; some rabbit and weed infestation.

Notes: This community is dominated by intergrades of *Casuarina pauper* with *Casuarina cristata* (L. Johnson pers. comm.) which are taller in habit than *Casuarina pauper* and with a denser crown. *Casuarina pauper* is the co-dominant species in the Belah–Rosewood country seen further west on the deeper sandier soils of the aeolian-fluviatile transition zone (see Community 4). *Casuarina cristata* has a more eastern distribution, occurring in a north-south band from south-eastern Queensland to the south-western slopes of New South Wales (L. Johnson pers. comm., Wilson & Johnson 1989). This intergrading population falls between the distribution of *Casuarina pauper* on the deeper red-brown sands further west (see Community 4), and *Casuarina cristata* on clayey grey or brown soils containing surface calcium (Wilson & Johnson 1989). The sandsheet supporting the intergrading community overlays a clay subsurface soil.

The main associate species in this community are *Geijera parviflora*, *Exocarpos aphyllus* and *Apophyllum anomalum*, with Rosewood uncommon and usually restricted to small groves or isolated trees. *Maireana georgei* (Satiny Bluebush), *Enchylaena tomentosa* and *Rhagodia spinescens* dominate the understorey in this woodland, while *Maireana pyramidata* is more prevalent in the Belah–Rosewood communities further west. A *Maireana pyramidata* association with *Maireana georgei* is said to occur mainly on soils that have not been seriously eroded (Stannard 1963). *Maireana georgei* is also noted here as having increased in number in certain sites in recent years.

This community is often somewhat mixed with a mosaic of *Callitris glaucophylla* woodland, open mallee and *Acacia pendula* woodland, especially north of Gunbar along the eastern edge of the mapped area. *Eucalyptus largiflorens* and *Acacia pendula* occur in low-lying areas whilst *Callitris glaucophylla, Hakea* species and groves of *Acacia melvillei* dominate the sandier rises within this community.

Map unit 29: Rocky Outcrop Woodland Complex

Structure: low woodland #; woodland to open woodland and open mallee woodland – shrubland ##

Main species: *Callitris glaucophylla* (White Cypress Pine) and *Eucalyptus intertexta* (Western Red Box) (B) throughout; *Eucalyptus vicina* (B) and *Brachychiton populneus* subsp. *trilobus* (Kurrajong) (B) on the summit; *Casuarina pauper, Alectryon oleifolius* subsp. *canescens* and *Eremophila mitchellii* (Budda) (B) on the lower slopes.

Associated Species: *Geijera parviflora* and *Exocarpos aphyllus* on lower slopes; *Pandorea pandorana* (Inland Wonga Vine) (B), *Dodonaea lobulata* (B), *Cheilanthes austrotenuifolia* (Rock Fern) (B), *Pleurosorus subglandulosus* (B), *Thysanotus patersonii* (Twining Fringe Lily) (B) and *Arthropodium minus* to summit; *Beyeria viscosa* (B) and *Actinobole uliginosum* at summit.

Landform: Footslopes, ridges and crests of low rocky outcrops. Low relief erosional rocky outcrop of sandstone-conglomerate geological type (Norris & Thomas 1991). Bevelled and rounded hills with rocky cliffs of quartzite, sandstone and conglomerates (Walker 1991).

Soils: Brown to red-brown clay-loam to sandy loam with surface stones and gravel, overlying a sandstone-conglomerate substrate. Sandstone lithosols to red earths comprising shallow sands, loams and clay-loams, with a stony or gravelly surface (Norris & Thomas 1991).

Occurrence: Warranary Hill in the Warranary Range, north-west of Roto in the far north-east of the Booligal map (Fig. 30). This is the only rocky outcrop that exists within the mapped area and as such this vegetation community is not typical of the Hay Plain.

Condition: Moderate to severe rabbit infestation and grazing and trampling by goats.

Notes: There is a distinct zonal distribution of species from the footslopes to the summit of the outcrop. Mixed *Callitris glaucophylla* and Belah–Rosewood, with *Geijera parviflora* and *Exocarpos aphyllus* dominate the footslopes. A distinct *Casuarina pauper* zone occupies the lower slopes with *Dodonaea lobulata* and *Eremophila mitchellii*. *Callitris glaucophylla* dominates from the middle slopes to the crest, with *Eucalyptus intertexta* coming in on the upper rocky slopes and ridges. Mixed *Callitris glaucophylla* and *Eucalyptus intertexta* persist to the top where *Eucalyptus vicina* (Fig. 29) and scattered *Brachychiton populneus* appear, constituting a mixed summit woodland.

Other potential associate species within this complex were recorded for a site of similar geological type in the Keginni Range further north (Norris & Thomas 1991).

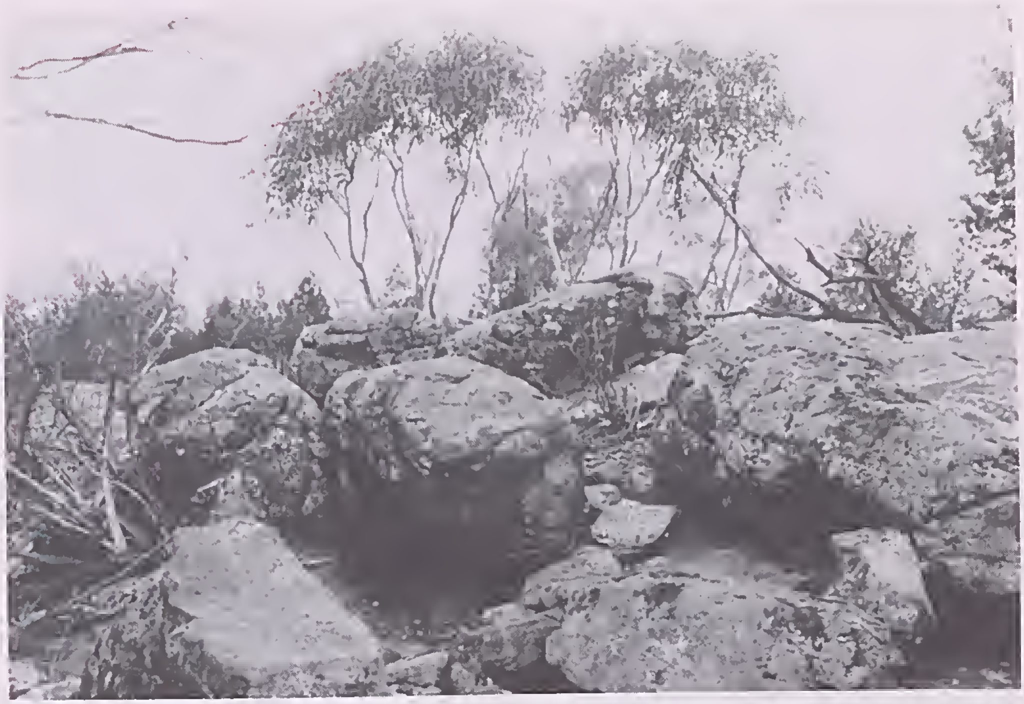

Figure 29. *Eucalyptus vicina* and scattered *Callitris glaucophylla* on the rocky summit of Warranary Hill (community 29), north-east of Roto in mid-spring.

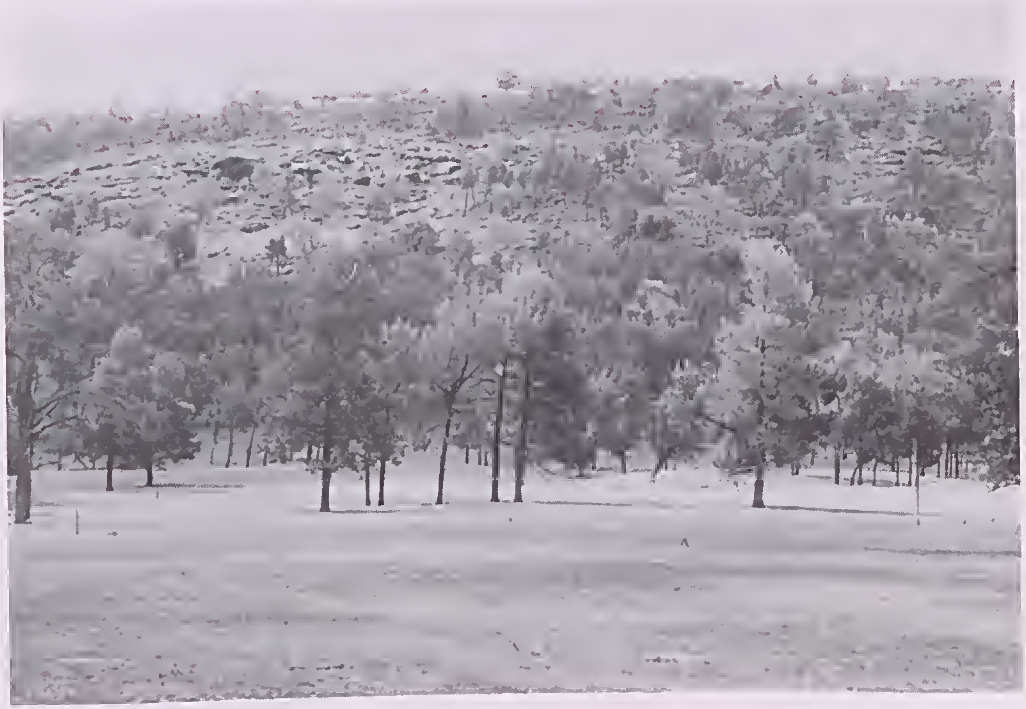

Figure 30. Warranary Hill north-west of Roto, with *Callitris glaucophylla* from footslopes to summit, and *Casuarina pauper* on lower slopes; (community 29); mid-spring.

These include *Acacia aneura* (Mulga), *Acacia doratoxylon* (Currawang), *Acacia decora* (Western Golden Wattle) and *Cheilanthes austrotenuifolia* (Rock Fern). Other species recorded for the site by the same authors include *Pleurosorus rutifolius, Calotis cuneifolia, Calotis hispidula, Sigesbeckia australiensis, Stuartina muelleri, Geococcus pusillus, *Silene gallica, *Stellaria media, *Chenopodium murale, Fimbristylis dichotoma, Phyllanthus fuernrohrii, *Medicago laciniata, Gonocarpus elatus, Isotoma axillaris, Eucalyptus vicina, Eucalyptus morrisii, Eragrostis lacunaria, *Lamarckia aurea, Thyridolepis mitchelliana, Eriostemon linearis* and *Hybanthus monopetalus.*

Walker (1991) describes the vegetation of Warranary Hill. *Callitris glaucophylla, Eucalyptus intertexta, Acacia aneura, Senna* species and various grasses and forbs occur throughout. *Eucalyptus morrisii, Acacia doratoxylon, Eriostemon linearis* (Narrow-leaf Waxflower) and *Eremophila serrulata* (Green Fuchsia Bush) occupy the crests and upper slopes, with *Eremophila mitchelii, Eriostemon linearis* and *Pandorea pandorana* on the lower slopes. *Eucalyptus populneus* subsp. *bimbil, Acacia decora, Dodonaea viscosa* subsp. *angustissima* and *Eremophila sturtii* are seen along drainage lines.

Rocky outcrops tend to receive little grazing due to their relative inaccessibility to stock. Feral goats, however, are a major problem in rocky areas, causing much damage in high numbers by grazing and trampling native vegetation. Rabbits are also a problem in the sandier soils of the footslopes where they undermine root systems and cause massive soil erosion. Both goats and rabbits were observed on Warranary Hill.

Open Areas (OA)

These are highly disturbed areas with a vegetation cover of annual or short-lived perennial grasses, herbs, forbs and few shrubs. Open Areas result from intense grazing, clearing and fire. Introduced pasture species usually predominate such as **Hordeum leporinum, *Lolium perenne, *Avena fatua* and **Medicago* spp. The composition of annual species changes seasonally but may also include *Erodium* spp., asteraceaeous herbs such as *Rhodanthe corymbiflora, *Cotula bipinnata* and *Podolepis muelleri*, annual saltbushes and *Swainsona* species. Weeds may also dominate the more disturbed Open Areas such as road verges and heavily used paddocks. Infestations of **Echium plantagineum* (Patterson's Curse), **Arctotheca calendula* (Capeweed) and **Brassica* spp. are particularly common on the Hay Plain.

Cleared Areas (C)

These areas have been almost entirely cleared of natural vegetation and often cultivated for agricultural purposes. Intensive irrigation farming on the Murray River and Edward–Wakool floodplains has led to almost complete clearing of native woodlands, shrublands and grasslands in these areas. Much of the cleared country north of the Murray River contains remnant stands of *Callitris glaucophylla, Eucalyptus microcarpa* or *Acacia pendula* that have been cropped right up to the trees. Larger areas of these remnant trees have been mapped but are essentially a cleared unit. Remnants are indicated in brackets after the C symbol.

Floristic Composition

A species list for the mapped area compiled from the current survey and published lists is given in Appendix 1. A total of 383 species from 68 families were recorded for the mapped area during the present survey. The number of species recorded for the riverine plain as a whole rises to 977 if previous surveys are included. Leigh and Mulham (1977) reported many aquatic and escapee species not recorded for the present survey, while other surveys concentrated on particular habitats such as riparian situations (Margules & Partners *et al.* 1990). The record is dominated by species from the Poaceae (150 species or 15 %), Asteraceae (150 species or 15 %), Chenopodiaceae (83 species or 9 %) and Fabaceae (74 species or 8 %). A large proportion of species recorded are exotic: 21 per cent from the present survey, a figure which rises to 40 per cent including other records.

Several extensions of range were recorded during the survey for a number of species (Appendix 1). Four species are new records for the South Western Plains botanical subdivision while ten are unsubstantiated new records for New South Wales (Jacobs & Pickard 1981, Harden 1990–92). Twenty-seven taxa have not been recorded in any previous survey on the Hay Plain, although many of these were recorded from mallee and rocky outcrop communities atypical of the vegetation of the Plain. Fifteen of the species recorded have restricted distributions in the Western Division of New South Wales (Pressey *et al.* 1990) while eight are listed as rare, vulnerable or endangered, and one species as extinct (Briggs & Leigh 1988) (Table 5).

The composition of annual and short-lived perennial species varies from year to year and most of them are widespread and not specific to any particular community. Species turnover between seasons in arid communities is considerable, and seasonal samples only represent a fraction of the total species richness (Fox 1990). *Callitris* Mixed Woodland (Community 16) showed the highest species variability of all communities sampled on the Plain, because of the many associated trees and shrubs. Grove-forming species such as *Alectryon oleifolius*, *Acacia melvillei*, *Senna* spp. and *Dodonaea* spp. often form localised communities. Mallee areas exhibited considerable variability in understorey species associated with small-scale changes in soils and geomorphology. Many of the tree-dominated communities showed some degree of structural variability. *Eucalyptus camaldulensis* exhibits both open forest and woodland proportions while *Eucalyptus microcarpa* may attain forest dimensions within riparian situations. Mallee species that have low and multi-stemmed growth forms in mallee shrublands may elsewhere be tall and single-stemmed, forming woodlands.

Discussion

Distribution of the vegetation communities

The major cause of variation in vegetation type is an interaction between soil moisture and rainfall, in particular depth of wetting (Noy-Meir 1974). With the move from sandy to clayey soils the moisture regime changes from one of deeper, easily available moisture to shallow, marginal moisture. The associated vegetation communities have adapted to each of these regimes. Most annual species die once the temporary topsoil water is depleted, but as long as it persists, the faster root and shoot growth of annual species gives them the competitive advantage over the perennials. As the depth of wetting increases, the competitive advantage shifts from shallow-rooted to deep-rooted species.

Soil fertility, particularly in phosphate, may be a secondary factor determining vegetation composition (Noy-Meir 1974). *Maireana sedifolia* dominates on calcareous soils where limestone nodules exist within the first 30 cm of the surface (Beadle 1948). *Atriplex vesicaria* grows in grey clays which are mildly alkaline and contain calcium carbonate (Beadle 1981).

Fluvial influences

The alluvial landscape dominates the Hay Plain, with some minor lacustrian elements. The characteristic vegetation communities are the various chenopod shrublands, notably *Atriplex vesicaria* shrubland, as well as the *Eucalyptus camaldulensis* and *Eucalyptus largiflorens* woodlands that fringe the rivers and creeks and extend out across the lower floodplains.

The grey clay soils of the Plain support different vegetation communities at different levels. The lowest, most water-retaining floodplains and depressions carry *Muehlenbeckia florulenta* scrub, *Eragrostis australasica*, *Eucalyptus camaldulensis* forest and other species tolerant of regular inundation. *Eucalyptus largiflorens* woodlands and *Chenopodium nitrariaceum* shrublands are found at slightly higher levels on the floodplain. The slightly elevated brown clay plains adjacent to the Murray River south of Deniliquin carry *Eucalyptus microcarpa* and *Allocasuarina luehmannii* remnants. These were some of the first areas to be cleared and cropped due to the fertile soils and their proximity to an irrigation source. Relatively large and dense areas of River Red Gum forest occupy the wide floodplains directly adjacent to the Murray River.

Saltbush (*Atriplex*-dominated) shrublands occur on the level, slightly saline plains and exist within the mapped area at their eastern and southern limits. Areas that receive water run-on usually have deeply cracking clays which give deep rooting species like *Atriplex nummularia* a moisture advantage (Dalton 1988). Remnant shrublands of this species are thus found on lower lying areas of the Plain. More compact clays which have a shallower wetting profile give shallow rooting perennial species such as *Atriplex vesicaria* the competitive advantage. *Atriplex vesicaria* and *Maireana aphylla* shrublands dominate the vast level plains, with *Sclerostegia tenuis* growing in more saline situations. These communities show varying degrees of degradation and most comprise often large areas of species indicative of disturbance such as *Nitraria billardierei*, *Sclerolaena muricata* and *Sclerolaena tricuspis*. The area supporting *Atriplex vesicaria* was certainly much greater prior to grazing, which has allowed the spread of more competitive species such as *Maireana aphylla* where the saltbush has been removed or thinned.

Acacia pendula woodland is also found on alluvial plains, occupying level to depressed grey clay plains or red-brown earths at slightly higher levels on the floodplain. It occurs within the mapped area at its western limit in south-western New South Wales. In this lower rainfall zone it occurs on heavier clay soils which retain moisture better while further east the surface soils supporting *Acacia pendula* are loamier (Moore 1953). Heavily grazed areas in the east of the mapped area which once supported *Atriplex vesicaria*, *Acacia pendula* and *Atriplex nummularia* are now disclimax perennial grasslands or, where grazing pressure continues to be high, annual grasslands comprising introduced pasture species (Moore 1953, Beadle 1948, Wilson & Graetz 1979).

Prior stream remnants which take the form of low oval-shaped dunes and old raised stream beds, provide minor topographic relief to the alluvial landscape. The coarser textured soils of these landforms carry mixed *Callitris*-dominated woodlands and *Maireana pyramidata* shrublands and are highly vulnerable to degradation due to the erodible nature of the soils. Rabbits are a particular problem in these sandier areas as the soil provides much better burrowing conditions, compared to the more compact clays of the surrounding plains.

Aeolian influences

The aeolian sandsheets predominating in the west and north of the Hay Plain mark the transition from fluvial to aeolian landscapes. Major changes in the vegetation occur here, as Belah–Rosewood open woodland and mallee and bluebush shrublands replace the low, uniform chenopod shrublands and grasslands of the alluvial plain. Aeolian forces also shape minor elements on the alluvial plain itself. An indicator of aeolian influences and sandier soils on the alluvial plain is the presence of *Callitris glaucophylla, Hakea* species and other mixed woodland species (Beadle 1948). While their presence may indicate the existence of a prior stream bed, larger rises supporting these species may be source-bordering dunes comprising the coarser soils of prior streams redeposited by wind action (Butler *et al.* 1973). *Callitris glaucophylla* occurs extensively on deeper, sandy soils and on rocky outcrops further north to north-east. Lunettes and scalded plains supporting bluebush shrublands are also geomorphological features with aeolian origins. The soils of aeolian landforms tend to be coarse-textured and are susceptible to erosion once the fixing vegetation cover is removed (Semple & Eldridge 1989).

Small areas of mallee encroach on the mapped area and are primarily of the sandplain type with a shrubby understorey, although some dune-crest mallee carrying *Triodia scariosa* occurs in the north-east. Much of this mallee is of the multi-stemmed 'whipstick' form indicating lower soil fertility and a history of regular burning (Beadle 1948, Noble *et al.* 1980). Remnants of large, old trees of the 'bull' mallee form are seen in heavily cleared areas along the north-eastern and western edges of the mapped area. Dunefields supporting mallee vegetation are more typical of the aeolian country to the west and north-east of the Hay Plain.

More typical of the aeolian landscape within the mapped area are open woodlands of *Casuarina pauper* (Belah) and *Alectryon oleifolius* (Rosewood) and *Maireana*-dominated shrublands. These dominate the sandsheets in the north to north-east of the Plain. *Maireana pyramidata* shrubland is a common community on the transition zone between aeolian country and alluvial plains and on the source-bordering dunes associated with prior streams. The duplex soils have a sandy topsoil 0.3 to 1 m thick, overlying an alluvial clay base (Semple & Eldridge 1989). Where limestone exists close to the soil surface *Maireana sedifolia* (Pearl Bluebush) dominates, and it becomes the dominant bluebush in the more calcareous earths further north and west (Beadle 1948). On the aeolian sandplains, in areas with low to medium grazing pressure, *Maireana pyramidata* forms the understorey to Belah and Rosewood. Belah–Rosewood is cleared preferentially to mallee and is prone to invasion by woody shrubs such as *Dodonaea viscosa* subsp. *angustissima* and *Senna* species.

Both mallee and Belah–Rosewood occur more extensively north of the mapped area with Belah–Rosewood dominating to the north-west and mallee to the north-east. *Acacia melvillei* is an important component of the aeolian landscape and commonly occurs in groves on sandier sites within Belah–Rosewood areas. Across the Hay Plain, groves of either Belah, Rosewood or both species occur within mixed woodlands on low sandy rises. Of particular interest in the central east of the mapped area is a sandsheet comprising duplex red-brown earth overlying clay supporting an intergrading population of *Casuarina pauper* with *Casuarina cristata* (Community 28).

Seasonal variability of the vegetation

The composition of annual and short-lived perennial grasses and herbs in open understoreys and pastures, varies considerably from season to season. Most of the winter and spring herbage comprises escaped pasture and other exotic species which are widespread throughout most vegetation communities. **Hordeum leporinum* (Barley Grass) is the most widespread and abundant grass species, especially after autumn rains but **Lolium perenne*, **Avena fatua*, **Bromus madritensis* and **Phalaris* species may become local dominants. *Medicago* species are also extremely abundant and widespread with burrs persisting throughout the driest periods. Both introduced and native species of *Erodium* are also common. Native annual species are also present in the flux of grasses and herbs that occurs after autumn and winter rains. *Rhodanthe corymbiflora, Rhodanthe floribunda, Podolepis muelleri, Daucus glochidiatus, Brachycome lineariloba, Pycnosorus pleiocephalus, Daucus glochidiatus, Swainsona procumbens,* and species of *Vittadinia, Wahlenbergia, Ptilotus* and *Goodenia* are some of the more showy species. Annual saltbushes such as *Atriplex lindleyi, Atriplex conduplicata, Atriplex pseudocampanulata* and *Atriplex leptophylla* are also a common component of the springtime herb layer in many communities.

The availability of water is the major climatic limit to plant growth on the Hay Plain. Temperature is also important in that it directly affects evaporation and transpiration. Winter is generally the period most favourable for plant growth, more so in the south where annual rainfalls are higher and more reliable. Most annual species grow in the winter months under these more favourable moisture regimes while summer growing and long-lived perennial species have developed strategies to either tolerate or avoid drought. Perennial *Atriplex* species require relatively little moisture for continued survival and growth. The high concentration of soluble salts in the plants and fine leaf hairs facilitate water absorption and prevent water loss during dry periods (Knowles & Condon 1951). Annual and short-lived perennial species are able to evade the hotter months and drought by completing their life cycle after one reasonably heavy fall of rain. Perennial shrubs such as *Atriplex vesicaria, Atriplex nummularia, Chenopodium nitrariaceum* and *Maireana aphylla* depend to a large extent on winter rains for germination and establishment (Dalton 1988).

The abundant annuals produced during winter, as well as some perennial grasses, die off in late spring to persist as dried stubble or surface litter. The perennial bushes remain green throughout the year, although portions may die back or shed leaves in excessively dry and hot summers to conserve moisture (Knowles & Condon 1951). Perennial grasses such as *Danthonia caespitosa* also produce a flush of growth with winter rains. They are better equipped to take advantage of unseasonal rainfall events than annual grass and herb species because they can regenerate vegetatively as well as from seed. They will however, dry off during the average hot summer (Dalton 1988). Competition may give annual species a seasonal advantage over perennial ones. After winter rainfall, fast-growing annual species rapidly exploit the readily available surface moisture, while during summer perennial species have the advantage of being able to tap deeper water supplies in the soil (Noy-Meir 1974).

Modifications to the natural vegetation due to land use

Rapid change to the natural vegetation of the Hay Plain came about with the introduction of sheep grazing and other farming practices. The spread of rabbits has also had highly destructive effects on the landscape.

Pre-European vegetation

The composition of the original saltbush vegetation on the Hay Plain prior to European impact has been debated. Some authors believe *Atriplex vesicaria* was the dominant species, others *Atriplex nummularia*. Most of the evidence suggests that *Atriplex vesicaria* was the more common and it is regarded in this and other publications as the original climax community (Beadle 1948, Knowles & Condon 1951). Beadle (1948) indicates that *Atriplex nummularia* was more abundant south of the Murrumbidgee River and in the eastern sector of the Plain. *Atriplex nummularia* shrublands are presently restricted to small remnant patches across the riverine plain while *Atriplex vesicaria* is much more widespread and abundant.

Moore (1953) presents evidence to show that the grasslands in the Narrandera, Urana and Jerilderie areas (in the south-east of the riverine plain) are disclimax or degraded communities once occupied by *Acacia pendula* and *Atriplex nummularia*. The original vegetation was an open woodland comprising trees of up to 10 m high with a well-developed shrub stratum which varied towards an *Atriplex nummularia* shrubland where the *Acacia* became infrequent. Associated shrubs included *Rhagodia spinescens, Enchylaena tomentosa, Maireana aphylla* and the poorly developed herb layer consisted mainly of *Danthonia* species, *Stipa falcata, Atriplex semibaccata, Maireana excavata* and various asteraceous herbs (Moore 1953). Similarly, much of the *Danthonia* grassland mapped in the current survey and by Beadle in 1948 has resulted from the clearing and grazing of the original communities.

Interestingly 'Coree', a property east of the current study, contains a significant area of *Atriplex vesicaria*, possibly occurring here at its south-eastern limit in Australia (Moore 1953). *Atriplex vesicaria* may have been much more common in these areas but was also grazed out. Moore (1953) also states that the original woodlands in the south-eastern riverine plain were open communities with a well-developed herbaceous stratum dominated by *Themeda australis*.

Grazing disturbance

The modification to the natural vegetation by sheep and cattle grazing on the Hay Plain has been immense. As the dominant land use, sheep grazing is concentrated on the rangelands, while cropping prevails closer to rivers and other water sources for irrigation. Not a single paddock appears to have escaped stock disturbance of one sort or another. The least disturbed areas of native vegetation exist in exclosures, home paddocks and reserves where stock have been excluded. A 43 ha exclosure seen in 1990 on 'Waterloo' south-east of Hay, has remained ungrazed for approximately 25 years and displayed great native species diversity and density of vegetation. Some of these sites however, especially those with loamy to sandy texture-contrast soils, may show significant degradation caused by rabbits and other feral animals.

The effects of grazing on native vegetation can range from complete clearing of perennials and their replacement by other species, to minor defoliation of perennial shrubs, trees and grasses. Grazing of seedlings also directly prevents regeneration in many communities. Some communities are partially modified by the thinning of the perennial vegetation when browsed by stock, which allows opportunistic species to become established. This is often seen in paddocks that are rotationally but intensively grazed in the short term. Species especially palatable to stock may be completely denuded and destroyed if stock rates are high and grazing pressure intensive. *Atriplex vesicaria, Atriplex nummularia, Maireana pyramidata* and *Maireana aphylla* are removed by inappropriate grazing, particularly with continuous heavy grazing (Beadle 1948, Leigh & Mulham 1965). These species may be replaced by opportunistic or exotic plants such as *Sclerolaena* species, thistles and introduced grasses. Some shrubland areas have been so heavily grazed that the original species have been entirely replaced by dense shrublands of *Nitraria billardierei, Sclerolaena muricata* and *Sclerolaena tricuspis* or by a suite of exotic annual grasses. Within most vegetation communities, particularly those with a more open structure, introduced annual and short-lived perennial grasses constitute the ground cover between scattered trees and shrubs. Invasion by other pasture species such as *Medicago* spp. and by various asteraceaeous herbs is also common. The ecological degradation of original plant communities to areas containing entirely disturbance-indicator species or annuals is a common result of grazing and clearing pressure on the Hay Plain.

It appears that sheep are highly selective even under conditions of low pasture availability (Leigh & Mulham 1966a, 1966b & 1967, Robards *et al.* 1967). In grazing trials the diet composition rarely conformed with that of the perennial pasture, a large proportion consisting of annual species such as **Hordeum leporinum* and **Medicago polymorpha*. Only in the summer when these are not available, were the dominant perennials grazed, as well as dry material such as medic burrs. In summer when very little other material was available, *Atriplex vesicaria* made up 90 per cent of the diet (Leigh & Mulham 1967). Within a *Maireana aphylla* shrubland, this species and medic burrs were favoured in summer. In winter there is a greater proportion of annual forage produced in the *Maireana aphylla* shrubland than in the *Atriplex vesicaria* shrubland (Leigh & Mulham 1966b). Grazing by native mammals appears to have a less damaging affect on chenopod shrublands. In areas where kangaroos congregate in large numbers they can remove all herbage in a similar manner to sheep. In contrast, however, they usually have little apparent effect on chenopod shrublands or tree seedlings (Wilson *et al.* 1984). Surveys have shown that kangaroos consume more grass than sheep (Wilson & Harrington 1984) and that red kangaroo populations are higher in mulga and box woodlands and *Danthonia* grasslands than in saltbush areas (Dalton 1988). Local variations in numbers are controlled by available herbage and shelter and population explosions during times of drought may have a negative effect on the already stressed vegetation.

While not observed during the present survey, some authors suggest that infrequent or short intensive periods of grazing actually increase shrub vigour and density. Osborn *et al.* (1932) and Knowles and Condon (1951) suggest that grazing by stock may have a pruning effect on *Atriplex vesicaria* promoting vigorous growth and compact bushes. If grazing was too heavy, however, shrubs started to deteriorate to the point of complete destruction under extreme conditions. Heavy intermittent grazing has been reported to improve the vigour of *Atriplex vesicaria* as well as seedling establishment (Ratcliffe 1936, Leigh & Mulham 1966a). It has also been suggested that this species may exhibit adverse symptoms in the absence of grazing, such as producing a large, scrappy form (Clift *et al.* 1987). Clift (1989) suggested that ungrazed or lightly grazed stands were often the first to experience dieback and were subsequently the slowest to regenerate. Other authors conclude that light grazing is more harmful to the vigour of *Atriplex vesicaria* communities than heavy or no grazing (Osborn *et al.* 1932). Similarly, infrequent or short intensive periods of grazing may actually increase plant species diversity within a community, a phenomenon occasionally observed along stockroutes within *Atriplex vesicaria* shrubland. These modifications to the vegetation are seen from the pastoral viewpoint of maximising grazing productivity. In terms of habitat sustainability such results may be degradational.

Modification of the original understorey due to grazing pressure is also common. An example of this is the *Acacia pendula* and *Atriplex nummularia* alliance described by Beadle (1948) and Moore (1953) which no longer exists today. The disappearance of the community is attributed to sheep grazing, bushfires, the severe drought of 1875-1877, the felling of *Acacia pendula* for stock feed and the use of the timber for firewood (Moore 1953). *Atriplex nummularia* is eaten readily by stock (Cunningham *et al.* 1981) and has been completely cleared as the understorey component of *Acacia pendula* woodland communities, to be replaced by perennial native and annual exotic grasses. Other vegetation communities have had their understoreys severely or completely cleared by direct grazing or trampling. Many *Eucalyptus largiflorens* and most *Callitris* woodlands have lost their original shrubby understoreys to grazing, with a replacement ground cover of annual and short-lived perennial grasses and herbs.

The shrubland and grassland communities on the Hay Plain may be regarded as various stages in a succession after grazing disturbance. A climax vegetation community is one which is in equilibrium with its environment and is essentially a stable community over a relatively long period (Moore 1953). A community in disclimax phase has undergone changes of varying degrees as a direct result of land use practices such as grazing, clearing and burning. The grassland communities of the Hay Plain are considered to be disclimax communities with various degrees of degeneration in evidence (Moore 1953, Wilson & Graetz 1979). In any part of south-western New South Wales, *Danthonia* and *Stipa* species are not found as dominants except under grazing while *Chloris* species dominate only in areas subject to heavy or severe grazing (Moore 1953).

The successionary process can be also be seen in scald reclamation patterns where over the years the scalds become revegetated with the surrounding dominant matrix of vegetation via a number of intermediary communities. In the short term, the larger scalds appear to be colonised by species that are disturbance indicators such as *Nitraria billardierei* and *Sclerolaena* species, *Maireana aphylla*, annual and short-lived perennial grasses such as **Hordeum leporinum* and **Lolium perenne* and annual herbage, particularly medic and other pasture species. The course of degeneration from healthy, dense Bladder Saltbush shrubland to bare scalded areas under grazing pressure can be followed. *Atriplex vesicaria* is initially replaced with *Maireana aphylla*, followed by *Sclerolaena* species and annual saltbushes, annual herbs and grasses and finally *Nitraria billardierei*. Scalding occurs after extreme grazing has eliminated even the relatively unpalatable *Nitraria billardierei* (Dalton 1988, Beadle 1948). Various states of ecological degradation can be monitored via these species.

Regeneration of many species is directly prevented by sheep grazing. Many shrubby understorey species are removed and any regeneration is prevented by persistent grazing. Trees of *Callitris glaucophylla* are not regenerating due to grazing pressure and older stands will ultimately die out. Regeneration of this species is rarely observed in the presence of stock and rabbits (Semple 1987b) while grazing herbivores also severely limit regeneration of *Casuarina pauper* and *Alectryon oleifolius* (Chesterfield & Parsons 1985). Protection from grazing promotes regeneration of key community species as well as the shrubby understorey.

Trampling by stock may also have a deleterious effect on vegetation leading ultimately to erosion. This occurs mostly in places of concentrated stock gathering such as watering points. Osborn *et al.* (1932) suggest that occasional trampling has the effect of planting seed, resulting in the overcrowding of bushes in an *Atriplex vesicaria* shrubland.

Saltbush and bluebush shrublands are considered to be of low resilience due to their susceptibility to overgrazing and the instability of the soils with vegetation removal (Graetz & Wilson 1984). Despite some recovery of *Atriplex vesicaria* after the dieback event of 1977–1983, many areas on the Hay Plain have still not recovered. Twenty-eight per cent of the country which previously carried healthy saltbush is still in a degraded state, particularly those areas south of Hay and between the Lachlan and Murrumbidgee Rivers (Clift *et al.* 1989, Semple 1989). Grazing pressure and mismanagement of regenerating stands appears to be the cause.

Clearing and cropping

Clearing for agriculture has the most extreme effect on the natural vegetation in that it is removed completely and regeneration is prevented. Irrigated crop growing is a major farming industry on the arable lands adjacent to major rivers and creeks. Within the mapped area, the floodplain country of the Murray River has been extensively cleared and cropped, primarily for rice, fruit and wheat. Few intact areas of native vegetation remain, most existing as remnant trees within cropped paddocks. The less extensive floodplains of the Murrumbidgee and Lachlan Rivers further north have been irrigated and cropped to a lesser extent. Some cropping is carried out in the dry lake basins north-west of Booligal and south of Ivanhoe, mostly after infrequent flooding events.

Logging

Many areas of the Hay Plain that were once wooded or forested have been cleared or thinned. *Callitris glaucophylla* was used for building and fencing and has been cleared considerably. *Acacia pendula* has been similarly cleared in the east of the Plain. River Red Gum timber is also highly valued, for heavy building work, railway sleepers, fencing and furniture making; logging of this species is the major activity in the State Forests on the Murray and Murrumbidgee Rivers. Charcoal production using River Red Gum logs and offcuts is an old industry maintained today at Mathoura. The original composition of these communities is also modified by logging, and many woodland and open forest areas are consequently prone to weed invasion. Timber-cutting in the Barmah–Millewa forests on the Murray River has altered their structure, from predominantly large old trees with patches of younger trees to young trees with few of the original forest giants (Somerville 1988).

Salinity

The removal, recycling and regulation of ground water is disrupted with the removal of vegetation. Without plant cover to regulate it, the water table rises, bringing dissolved salts to the soil surface and resulting in soil salinity. Surface salinity is a particular problem in areas of heavy irrigation and other situations where there is a high influx of water and little vegetation cover. Existing vegetation can also die off with increasing soil salinity, to be replaced by more salt-tolerant species. In extreme cases the result is a saltpan on which few plants can grow. Salinisation is a problem in some irrigated areas along the Murray River and appears to be more severe in the intensively irrigated areas across the river in Victoria. However in the Tullakool Irrigation Area near Wakool, rising salinity has necessitated the installation of a subsurface drainage system and evaporation ponds.

Erosion

Soil erosion is exacerbated with the removal of vegetation. Scalding, the removal of the top soil horizon by wind action, is commonly seen on the Hay Plain. Duplex and deeper sandy soils are particularly scald-prone, as the sandy to loamy surface soil is removed, exposing the heavier clay B-horizon. Abraham (1987) notes that the red-brown earths occurring in the eastern Hay Plain are texture-contrast soils with hard-setting loamy topsoils which are not as susceptible to scalding as the sandier topsoils occurring as sandsheets further west. Source-bordering dunes, lunettes and low sandy rises are also susceptible to windsheeting (the removal of thin surface layers of soil by wind) and drift (the removal and accumulation of sand either on the eroded surface or against adjacent obstructions) (Dalton 1988, Condon & Stannard 1957).

The regeneration of scalded areas is limited by high exposure of the surface soil to temperature, evaporation and wind movement, and by the low water infiltration rates and limited seed source in the soil (Beadle 1948b). Abraham (1987) believes that the rate of scald revegetation is slowing down, and that many remaining scalds are unlikely to revegetate naturally as their sloping surfaces do not hold water as efficiently as the already reclaimed flat surfaces. *Atriplex vesicaria* is reported to be the most successful native shrub for sowing onto scalded and degraded land, followed by *Atriplex nummularia* to a lesser extent (Muirhead & Jones 1966, Alchin 1974). Germination rates are low and seeding rates therefore need to be high.

Erosion is exacerbated by the presence of rabbits which disturb the soil, often on a massive scale. Huge warrens were observed in many sandy sites on the Plain, often exposing the root systems of existing trees. Sheep and cattle remove existing vegetation by grazing and cause soil erosion by trampling. Gully erosion due to water runoff is not common on the Hay Plain but was observed in several heavily irrigated sites in the south.

Feral herbivores

Of all the animals introduced to inland Australia rabbits have had the greatest impact on the environment. Grazing by rabbits, particularly of seedlings, contributes to the overall land degradation by preventing regeneration of community dominants. *Callitris* woodlands on prior stream ridges and low dunes and the Belah–Rosewood sandplains have been most affected by rabbit invasion. Away from the sandier habitats, *Atriplex nummularia* and *Nitraria billardierei* shrublands on the alluvial plains provide excellent shelter for rabbits (Dalton 1988). The eastern area of the Hay Plain, bounded by Booroorban, Four Corners and Carrathool has been described by local sources as the most rabbit-infested area of the Plain (Dalton 1988).

Pigs, goats and foxes continue to be a problem in western New South Wales. Feral pigs are common in the swamp and floodplain areas of the Lachlan–Murrumbidgee confluence but are not so prevalent on the saltbush plains (Dalton 1988). Goats are a serious problem in rocky habitats and groups were observed on Warranary Hill within the study area, where the vegetation is noticeably cropped and there is some soil erosion.

Introduced plants

A major modification to the natural vegetation has been the introduction and establishment of exotic species and non-local native taxa. Many of these plants, particularly the introduced pastoral species and weeds, have become a prominent part of the landscape, usually dominating the winter pasture and ground layer within many vegetation communities. Introduced pasture species such as **Hordeum leporinum*, **Lolium perenne*, **Avena fatua*, **Medicago* and *Erodium* species have become so established as to dominate the herbaceous layer of most communities on the Plain. In the current survey, 21 per cent of the species recorded are introduced taxa (Appendix 1). Semple (1987a) found that a third of the species present within an ungrazed prior stream site were naturalised. The high proportion of naturalised taxa has serious implications for natural vegetation management on the Hay Plain.

Common woody species that have become naturalised include **Lycium ferocissimum* and **Nicotiana glauca*. Common herbs and forbs that have become pests in many areas of the Plain include **Xanthium spinosum*, **Echium plantagineum*, **Cirsium vulgare*, **Sonchus oleraceus*, **Arctotheca calendula*, **Heliotropium europaeum*, **Brassica rapa* and **Sisymbrium* species. Weed species may cause particular problems with revegetation projects and rehabilitation of natural vegetation. Vigilant weeding programs need to be carried out in such cases, where weeds impede desired plant growth. These species, carried in by rivers or introduced with domestic stock or cropping, continue to be dispersed by animals, winds and vehicles (Beadle 1981).

Nitraria billardierei, a native species, has successfully colonised many cleared and disturbed areas on the Hay Plain. Native woody shrubs such as *Dodonaea viscosa* subsp. *angustissima* and *Senna* species often colonise disturbed areas on sandy soils in dense monospecific thickets and are considered weeds by graziers as they reduce the grazing potential of the land. *Callitris glaucophylla*, relatively rare on the Hay Plain, is regarded as a woody weed in some parts of the western slopes and the Pilliga region because of its dense regrowth in these areas. Historical records indicate that natural fluctuations occur in the densities of native woody species. Denney (1992) suggests that the woody weed outbreaks are a successional stage that, if left alone, will slowly change towards the original woodland-grassland vegetation.

Natural modifications

Dieback events

The most recent and devastating modification to the vegetation on the Hay Plain has been the widespread dieback of *Atriplex vesicaria*. Between 1977 and 1983 dieback resulted in a decrease in the area of *Atriplex vesicaria* shrubland on the Plain by 53 per cent (Clift *et al.* 1987). It has since been replaced by shrublands of *Sclerolaena muricata, Sclerolaena tricuspis, Maireana aphylla* and annual or short-lived perennial grasses. Localised dieback of *Maireana pyramidata, Maireana sedifolia, Maireana aphylla* and *Atriplex nummularia* also occurred in some areas. At the time, many believed the future presence of *Atriplex vesicaria* on the Plain was in doubt, such was the severity of the dieback. The saltbush recovered somewhat with general regeneration from seedlings and reshooting after early summer rains in 1984, but did not completely regenerate in all areas, especially south of Hay (Clift *et al.* 1989, Semple 1989).

Dieback is believed to be a product of exceptional rainfall (Semple 1989). Shrubs send out shallow, short-lived feeding roots which prove inadequate during ensuing dry spells for plant survival. A lack of effective summer rain coupled with the above-average winter rain may promote strong competition from annual grasses and forbs which deplete the surface soil moisture. Other effects of above-average rainfall may be the disruption of normal *Atriplex vesicaria* growth, the strong competition between shrubs as well as from annuals and the proliferation of wilt-inducing pathogens. Caterpillars and weevil larvae (borers) are thought to contribute to saltbush death by defoliating the shrubs (Semple 1989). They are more likely to be secondary invaders as the low numbers seen were not consistent with defoliation and it seems that the caterpillar plagues coincided with, rather than initiated the dieback. Subsequent maintenance of the pre-existing grazing pressure in these areas is also detrimental to saltbush regeneration.

Fire

Aboriginal people regularly burned the grassland of the plains to promote the growth of young grasses and seeds, both to collect and to attract game (Mullins *et al.* 1982). The incidence of naturally occurring wildfires in the area is unknown although lightning strikes could certainly cause ignitions in woodland areas of the Plain. *Atriplex vesicaria* and *Atriplex nummularia* are naturally resistant to fire (Leigh & Mulham 1965), although they may be destroyed if sufficient fuel has built up between the shrubs in the form of dried grasses and litter. The regeneration of these species after fire is slow, especially if the seed source has also been destroyed (Hodgkinson 1983, Hodgkinson *et al.* 1984). *Maireana aphylla* and *Maireana pyramidata* are not as adversely affected by fire although their densities may be reduced after wildfire (Leigh & Noble 1981).

Grassland areas south-east of Hay were affected by fire in November 1990 which was ignited from the Sturt Highway. Widespread fires in 1991 also burned a huge area north-east of Booligal to Willandra Creek. Few shrublands remain in the eastern half of the map due to the combined effects of clearing, grazing and fires. Trees appear to have survived these fire events better and coppice growth was observed north-east of Booligal. The mallee in the north-east of the mapped area has a history of regular burning. Fires occurred in the Roto–Hillston region in 1940 and 1956 to 1957 (Denney 1992) and parts of the mallee country in the Cobar Shire, situated north of Roto, were burnt during the wildfires of 1974–75 (Noble *et al.* 1980). Much of the mallee here is of the 'whipstick' form, which is highly combustible. *Triodia*, commonly associated with whipstick mallee on the dune-crests, is also extremely flammable due to its high litter accumulation (Noble *et al.* 1980).

Drought

Drought is normally declared when at least 50 per cent of properties over a widespread area contain insufficient water or feed to sustain stock (Dalton 1988). The famous droughts of 1883–1885 and 1890–1894 resulted in substantial degeneration of saltbush and grassland pastures. Drought conditions bring additional grazing pressure and place stress on the natural vegetation. The felling of trees and lopping of foliage from various species such as *Casuarina pauper, Alectryon oleifolius, Geijera parviflora* and *Acacia pendula* for stock feed is a common practice during drought (Grant 1989).

Atriplex vesicaria has a high drought resistance, having the ability to absorb moisture through the leaves from rainfall and dew, due to the high concentrations of soluble salts in the leaves (Knowles & Condon 1951). Very fine hairs on the leaves assist in water absorption and collapse during dry periods to form a protective, water-retaining covering. The plant can also rapidly produce feeding roots following good rains and, if severe drought conditions prevail, it sheds leaves. Seemingly dead, defoliated bushes, often reduced to black sticks, may be in a condition that minimises water loss (Knowles & Condon 1951).

Flooding and high rainfall

Flooding events are essential for the survival of several major species on the Plain. *Eucalyptus camaldulensis* requires regular inundation for seed dispersal and establishment as does *Eucalyptus largiflorens* to a lesser extent. Lignum (*Muehlenbeckia florulenta*) grows rapidly during wet periods while *Chenopodium nitrariaceum* and *Eragrostis australasica* are also adapted to periods of inundation (Cunningham *et al.* 1981). Flooding influences the distribution of such communities by facilitating seed dispersal and initial establishment. The natural hydrology of the major rivers has been changed with river regulation practices and floods are not as common now as they would be naturally (Dalton 1988). The removal of vegetation cover and subsequent increase in erosion has increased the sediment loads in many rivers (Schumm 1968).

It has been suggested that the abnormally high rainfall years of 1973 and 1974 indirectly contributed to the widespread dieback of *Atriplex vesicaria* from 1977 to 1983 (see 'Dieback events' in this section). *Atriplex nummularia* is well-adapted to low-lying areas that receive extra run-on and can withstand long periods of inundation, even germinating in waterlogged soil. Plants of *Atriplex vesicaria* are not as flood-tolerant although the seeds are not affected and are the main means of regeneration after a flood (Dalton 1988).

Conservation of vegetation

The vegetation of western New South Wales is very poorly conserved, considering that many plant communities are threatened due to continuing land use practices (Benson 1989, 1991). Only about two per cent of the Western Plains is conserved in national parks or nature reserves (Benson 1988). The flora in agricultural zones is the most poorly conserved. Vegetation groups which have the poorest conservation status in New South Wales include inland *Acacia* shrublands and *Casuarina* woodlands, chenopod shrublands of the southern plains, box woodlands and communities of inland watercourses and floodplains (Benson 1989, 1991). The Hay Plain comprises a significant area of chenopod shrublands, semi-arid woodlands and riverine forest, constituting the heart of the Murray–Darling catchment area. Few of the vegetation communities representative of the Hay Plain are protected in reserves.

Willandra National Park (19 386 ha) and Goonawarra Nature Reserve (437 ha) are the only formal reserves within the mapped area (excluding Sandune Pine Flora Reserve, a relatively small reserve managed by the Forestry Commission, on the Murray River) representing a conserved proportion of only 0.45 per cent. The variety of vegetation communities within these reserves is limited and they do not adequately represent the botanical biodiversity of the Hay Plain. Willandra National Park was to have realised the conservation of riverine plain *Atriplex vesicaria*, but after 20 years of grazing protection it comprises mostly modified *Maireana aphylla* shrubland and open grassland. In the intensively irrigated areas south of Deniliquin, few areas remain in which the original vegetation still survives. There is an urgent need to protect key sites for preservation.

Significant vegetation communities

The most vulnerable communities on the Hay Plain presently are those growing on the sandy duplex soils of low rises, prior streams and sandplains. These soils are highly erosion-prone due to the combined effects of vegetation removal by overgrazing and undermining by rabbits. In a priority-order of vegetation communities for conservation in the southern Riverina, Brickhill (1985) lists *Callitris*-dominated and *Acacia pendula* communities as top-priority. Table 4 indicates the threats to and present conservation status of vegetation communities occurring on the Hay Plain.

Callitris glaucophylla Mixed Woodland (Community 16) and Prior Stream Remnant Woodland (Community 27) are vulnerable communities of particular concern. They suffer from removal of understorey species and the prevention of seedling establishment due to grazing and trampling by stock, undermining by rabbits and erosion due to vegetation loss. Notable sites include 'Steam Plains' and 'Zara' north of Deniliquin (Brickhill 1985), 'Oolambeyan' south-east of Hay, and the Booroorban, Tholobin, Puckawidgee and Edgar State Forests. The 'Steam Plains' and 'Zara' areas also contain unusual and rare understoreys of *Atriplex nummularia*. As well as being logged, the State Forest areas are often leased out to landholders and suffer intensive grazing pressure with little or no regeneration of tree species. The Tholobin State Forest is particularly degraded, with rabbit infestation, heavy logging and overgrazing. Immediate acquisition some of these sites will prevent the loss of these remnant old woodlands in future years. Fencing off some of these areas from stock and rabbits would allow natural regeneration of the pine and re-establishment of the shrubby understorey. The 'Zara' sandhills, which have been fenced-off in the past and are in a relatively natural condition, and sites within the Steam Plains, Puckawidgee and Edgar State Forests could be targeted for regeneration. The relative rarity of *Callitris* Mixed Woodland on the Hay Plain today and the degraded state of prior streams give these communities particular conservation significance.

The higher, red-earth floodplain country between Deniliquin and the Murray River also remains unconserved. This area contains remnants of *Eucalyptus microcarpa* woodland with *Allocasuarina luehmannii* and *Eucalyptus melliodora* (Community 24) and areas of *Callitris glaucophylla* woodland (Community 16). It has been almost entirely cleared for irrigation with cropping up to and below the trees. Small roadside remnants remain, some with well-developed shrubby understoreys of local *Acacia* and *Senna* species and their acquisition for formal reservation is particularly urgent. Areas of *Eucalyptus microcarpa*, *Eucalyptus melliodora* and *Callitris glaucophylla* are listed as high priority communities for conservation, with proposed sites at Wahgunyah and

Table 4. Present conservation status of and threats to vegetation communities occurring within the Booligal, Hay and Deniliquin-Bendigo 1:250 000 map areas (adapted from Brickhill 1985, Benson 1989 and Morgan & Terrey 1992).

Community	Threats	Effects	Conservation Status
1 Riverine Forest	forestry activities, river regulation, irrigation, clearing for cropping, grazing, recreational activities	minor reduction in range and populations, younger age class over much of its distribution	Inadequately conserved, vulnerable; some conserved in Goonawarra Nature Reserve (437 ha) along the Lachlan River but conservation status extremely poor along Murray and Murrumbidgee Rivers, the former containing the largest stands in Australia.
2 Black Box Woodland	grazing and cropping	major reduction in range and populations, major alteration of understorey, older age class over much of its distribution	Inadequately conserved but not threatened in the forseeable future; some conserved in Goonawarra Nature Reserve and Willandra National Park.
3 Mallee	grazing, cropping, significant changes in fire regime, rabbit invasion	major reduction in range and populations, major alteration of understorey	Adequately conserved in Nombinnie, Round Hill and Yathong Nature Reserves, and Mallee Cliffs National Park, outside the mapped area and not threatened in the forseeable future.
4 Belah-Rosewood	grazing, rabbit invasion, cropping	major reduction in range and populations, major alteration of understorey, little regeneration, older age class over much of its distribution	Inadequately conserved, vulnerable; very widespread and not conserved over its range.
8 Black Bluebush	grazing, rabbit invasion	minor reduction in range and populations	Poorly conserved but not threatened in the forseeable future. Pearl Bluebush poorly conserved and vulnerable.
11 Bladder Saltbush	grazing, cropping, dieback events	major reduction in range and populations	Poorly and inadequately conserved, vulnerable; none conserved on the Hay Plain

Table 4 (continued)

Community	Threats	Effects	Conservation Status
12 *Sclerostegia tenuis*	grazing, cropping, dieback events	major reduction in range and populations	Not conserved, vulnerable.
13 Canegrass	grazing, irrigation dryland cropping	minor reduction in range and populations	Inadequately conserved, vulnerable.
16 *Callitris* Mixed Woodland	grazing, rabbit invasion, cropping, some logging	major reduction in range and populations, major clearing and alteration of understorey, little regeneration, older age class over much of its distribution, soil erosion	Inadequately conserved, vulnerable; some areas endangered on the Hay Plain under current threats.
17 *Acacia melvillei* Woodland	grazing, rabbit invasion, cropping, some cutting for domestic firewood	minor reduction in range and populations	Not conserved over its range, vulnerable.
18 Lignum and *Chenopodium nitrariaceum*	irrigation and drainage, clearing for cropping and grazing	major reduction in range and populations	Inadequately conserved, vulnerable; some conserved within Goonawarra Nature reserve. Currently being cleared along the Murrumbidgee River for irrigation.
19 Old Man Saltbush	grazing	major reduction in range and populations	Not conserved, endangered; extinct in some regions and relatively rare on the Hay Plain.
21 Cotton Bush	grazing	overall increase in range and populations on the Hay Plain with Bladder Saltbush dieback	Vulnerable to overgrazing; conserved within Willandra National Park (19 386 ha), most of which comprises this shrubland.

Community	Threats	Effects	Conservation Status
23 Great Cumbung Swamp	irrigation and drainage, resulting from river regulation, grazing	minor reduction in range and populations	Inadequately conserved but not threatened in the forseeable future.
24 Grey Box Woodland	grazing and clearing for cropping	major reduction in range and populations, major clearing of understorey, little to no regeneration, older age class over much of its distribution	Not conserved, vulnerable to endangered; intact communities, especially with Yellow Box, rare on the Hay Plain. Some *Allocasuarina luehmannii* conserved off the mapped area but inadequately so.
25 *Acacia pendula* Woodland	grazing, cropping and some lopping for fodder	major reduction in range and populations, major alteration and clearing of understorey	Not conserved, endangered by clearing; intact Old Man Saltbush understorey extremely rare.
26 White-top Grassland	grazing and cropping	major reduction in range and populations	Not conserved but not threatened in the forseeable future.
27 Prior Stream Remnant Woodland	grazing, rabbit invasion, cropping	major reduction in range and populations, major alteration of understorey, little regeneration, soil erosion	Not conserved, vulnerable; some areas endangered on the Hay Plain under current threats.
28 *Casuarina pauper/ Casuarina cristata* Intergrading Population	grazing, cropping, some rabbit invasion	minor reduction in range and populations, major alteration of understorey	Not conserved, vulnerable; possibly cleared for cropping east of the mapped area.
29 Rocky Outcrop Woodland Complex	grazing, clearing, feral animals, significant changes in fire regime	minor reduction in range and populations, major alteration of understorey	Not conserved but not threatened in the foreseeable future.

Buckingbong State Forests, to the east of the mapped area (Brickhill 1985). Also unreserved are the small isolated sandhills of the Murray floodplain supporting *Callitris gracilis* subsp. *murrayensis* (Murray Cypress Pine). Small, unmapped and rare remnants of shrubs such as *Melaleuca lanceolata* and *Acacia rigens* occur around Deniliquin. Any small vegetation remnants in areas of intensive land use must be assumed to have a high conservation value (Morgan & Terrey 1992).

The conservation status of *Atriplex vesicaria* (Community 11) and other chenopod shrublands on the Hay Plain is considered extremely poor (Benson 1988). Large areas have been reduced to ephemeral grasslands with *Sclerolaena* species, or to *Maireana aphylla* shrublands, particularly around the Lachlan River in the north-east of the mapped area and south of Hay. The majority of the 19 386 ha of Willandra National Park is not considered representative of the vegetation on the Plain since no *Atriplex vesicaria* has been recorded there and has not returned after 20 years of grazing protection. The Park was established within highly disturbed and modified vegetation which was expected to return to a species mix close to that which existed before grazing (Lunnon 1988). The properties presently surrounding the Park contain mostly open annual grasses and herbfields where grazing pressure continues to be high. The present survey has indicated that the best areas of *Atriplex vesicaria* remain in little-disturbed sites such as exclosures and on areas only periodically and lightly grazed, such as certain stockroutes. The most extensive tracts occur north to north-west of Hay and west of Booligal; however these have declined considerably both in area and condition over the past 15 years, as a consequence of dieback events. Beadle (1948) mapped *Atriplex vesicaria* as far south as the Edward River with patchy areas further south. Small stands remaining between Moulamein and Wanganella represent the southern limit of its distribution on the Hay Plain. Any native shrublands south of this limit have been completely cleared, making the preservation of the southern-most remnants all the more significant. Further investigation into the causes of dieback is essential for the future survival and management of this community. The procurement of a more representative reserve, entirely protected from grazing and within the existing area of *Atriplex vesicaria* is needed to ensure the preservation of this important shrubland.

Remnant areas of *Atriplex nummularia* shrubland (Community 19) occur throughout the Hay Plain but its distribution is very patchy. Once much more extensive, it has been reduced to small relict areas, often around homesteads and in small holding paddocks. The shrub is also found as an understorey to Black Box, at sites between Moulamein and Wanganella and north-east of Hay, and on 'Steam Plains' with *Callitris glaucophylla*. The 'Steam Plains' site has been listed as the best remaining stand of this community and nominated as a proposed conservation reserve (Brickhill 1985). As a relatively rare type of native shrubland on the Hay Plain today, the protection of these remnants is highly desirable.

Acacia pendula is also inadequately represented in the conserved estate. Regeneration in the field is sporadic and young plants are often damaged by grazing, since the foliage is palatable to stock (Beadle 1981). Intact woodlands now only occur as isolated remnants, having been largely altered to short-lived perennial or annual grasslands. *Acacia pendula* requires detailed survey as a matter of priority to determine the options available for conserving representative areas (Morgan & Terrey 1992). A survey of *Acacia pendula* and *Acacia homalophylla* distribution in western New South Wales is currently underway (M. Fox in prep.).

The long-term future of tree species in the lower rainfall zone of the Hay Plain is also of great concern. Belah–Rosewood (Community 4) is very poorly protected throughout its range (Benson 1988) and remains unprotected within the mapped area. Grazing seriously limits the regeneration of *Casuarina pauper* and *Alectryon oleifolius* to the extent that the future of these species on pastoral land is regarded as severely threatened in the long-term (Chesterfield & Parsons 1985). *Alectryon oleifolius* in particular is highly palatable to grazing stock, rabbits and goats, and regenerates by suckers; seedlings are rarely found. *Casuarina pauper* regenerates by limited seedling production and suckering appears insufficient to perpetuate stands of the species (Chesterfield & Parsons 1985). A reduction in grazing pressure will also be necessary to protect the erosion-prone soils.

The conservation status of riparian and floodplain ecosystems of the Murray, Murrumbidgee and Lachlan River systems is extremely poor. There appears to be an urgent need to establish a reserve in the *Eucalyptus camaldulensis* forests of the Murray River which, except for Kemendoc Nature Reserve west of the mapped area, remain virtually unconserved in New South Wales. The largest stands of this species in Australia occur in the southern Riverina (Brickhill 1985). *Eucalyptus camaldulensis* is considered well conserved in Victoria in such reserves as Hattah–Kulkyne National Park (Murray–Darling Basin Ministerial Council 1987). Many of the most significant stands of the species in New South Wales are in State Forests and the continued logging is compromising the selection of representative conservation areas. At present no substantial River Red Gum forest is adequately conserved in New South Wales (Morgan & Terrey 1992). The forests of the Barmah–Millewah area form the only tall open forest on the western slopes and plains and remain unconserved. There is no doubt that the management of these forests for timber production very often has a detrimental effect on nature conservation (Somerville 1988). The flora reserves gazetted by the Forestry Commission are considered inadequate and the conservation of *Eucalyptus camaldulensis* in secure reserves free from all logging and grazing should be high on the conservation agenda (Somerville 1988).

The Black Box vegetation of the Murrumbidgee River is represented near Balranald in Yanga Nature Reserve but further representation in the east is desirable. The Murrumbidgee River is highly regulated within the mapped area and few suitable sites exist. Localities such as Darlington Point east of the mapped area could be targeted for conservation. Kinchega National Park south-east of Broken Hill reserves *Eucalyptus largiflorens* and some *Eucalyptus camaldulensis* on the Darling River (Benson 1988). One of the biggest threats to inland river systems is their contamination by chemicals and salts, and nutrient enrichment from fertilisers and livestock droppings that result in algal blooms. Changed flooding regimes due to river regulation have also affected regeneration of many River Red Gum and Black Box communities.

Other important unprotected vegetation occurs as ephemeral wetlands. Areas of *Muehlenbeckia florulenta* and *Eragrostis australasica* provide habitat for thousands of waterbirds when flooded (Pressey 1988). The Booligal wetland complex is associated with the Lachlan River downstream of Booligal and encompasses the Merrowie, Merrimajeel and Muggabah Creek anabranches. The channels and lake basins contain extensive stands of *Muehlenbeckia florulenta*, *Eucalyptus largiflorens* and *Eucalyptus camaldulensis*. Although containing these species, Goonawarra Nature Reserve is considered only marginal to, and not representative of, the Booligal wetlands (Pressey 1988). The Great Cumbung Swamp of the Lachlan–Murrumbidgee confluence is not protected at all by reserves. Inland reed swamps are commonly burnt to promote new green growth for stock while large areas of Lignum are presently being cleared for irrigation development on the lower Murrumbidgee within the mapped area (Pressey 1988). Other threats to wetland areas include the hydrological changes imposed by dams and weirs, sheep and cattle grazing (which commonly prevents the regeneration of Black Box and River Red Gum), logging, and lake-bed cropping which can cause salinity problems where irrigated (Pressey 1988).

Table 5. Species of particular conservation significance recorded for the Booligal–Hay and Deniliquin–Bendigo 1:250 000 map sheets. (A) Species nationally listed as rare or threatened (Briggs & Leigh 1988) and (B) species with restricted distributions in the Western Division of New South Wales (Pressey *et al.* 1990).

Risk Codes (Briggs & Leigh 1988)
2 Maximum geographic range of less than 100 km. **3** Range over 100 km but restricted to highly specific and localised habitats. **X** Species not recorded for at least 50 years and presumed extinct. **E** Endangered species at risk of disappearing within one or two decades under present land use. **V** Vulnerable species not presently endangered but at risk of disappearing over a longer period (20-50 years). **Ca** Adequately reserved with a total conserved population of 1000 plants or more. **Ci** Inadequately reserved with a total conserved population of less than 1000 plants.

Category and Priority Codes (Pressey *et al.* 1990)
Category 1 Species occurring only in the Western Division with a restricted distribution. **Category 2** Species occurring only in New South Wales with a restricted distribution within and outside the Western Division **Category 3** Species with a restricted distribution in the Western Division and also occurring interstate with **A** a small range and/or few records or **B** a wide range and/or many records. **Category 4** Species with disjunct occurrences in the Western Division with **A** the main population interstate and **B** the main population in New South Wales. **Priority 1** Protection measures in the Western Division will completely determine the survival of the taxon nationally. **Priority 3** Conservation of these taxa in the Western Division will influence their overall survival. **Priority 4** Protection in the Western Division is desirable to conserve the genetic variation within the ranges of these taxa.

(A) Taxa	**Risk Code**	**Habitat**
AMARANTHACEAE		
Ptilotus extenuatus Benl.	2X	Known from only two collections, one made in 1818 with no precise locality recorded and one from 'Zara' station north-west of Deniliquin in 1919. Despite numerous searches, it has not been collected for the past 73 years and is believed to have been grazed-out by domestic stock and rabbits (Briggs & Leigh 1988).
ASTERACEAE		
Brachycome papillosa G.L. Davis	3V	*Maireana aphylla* shrubland within Willandra National Park (present survey). Also recorded from *Atriplex vesicaria* communities on clay soils (Community 11) (Semple 1986, Leigh & Mulham 1977).
BRASSICACEAE		
Lepidium monoplocoides F. Muell.	3ECi	*Maireana pyramidata* shrubland (Community 8, present survey). Also recorded by Leigh & Mulham (1977) and Margules & Partners *et al.* (1990).
CHENOPODIACEAE		
Maireana cheelii (R.H. Anderson) P.G. Wilson	3V	*Atriplex vesicaria* shrubland (Community 11) (Semple 1986, Leigh & Mulham 1977).

CYPERACEAE *Eleocharis obicis* L.A.S. Johnson and O.D. Evans	3V	Depressions with *Eragrostis australasica* (present survey, Community 13) but also recorded from *Atriplex vesicaria* (Community 11) and *Atriplex nummularia* (Community 19) shrublands (Cunningham & Milthorpe 1981)
ERIOCAULACEAE *Eriocaulon australasicum* (F. Muell.) Korn	2VCa	Recorded as a collection in 1853 from 'wet places along the Murray towards junction of Murrumbidgee' (Mulham & Jones 1981).
FABACEAE-FABOIDEAE *Swainsona murrayana* Wawra	3V	*Atriplex vesicaria* (Community 11), *Acacia pendula* (Community 25) and *Maireana aphylla* (Community 21) communities, the latter in Willandra National Park (present survey).
Swainsona plagiotropis F. Muell.	3ECi	Roadsides, rail reserves, stock routes and areas of lightly grazed unimproved pasture, in *Danthonia* spp./*Enteropogon acicularis*/*Stipa* spp. grassland communities. Found on the plains country around Jerilderie and on the Murray Valley plains south of Echuca in Victoria. One site for the species is reserved in Wharparilla Flora Reserve near Echuca in Victoria, however the population presently comprises only two individuals (Appleby *et al.* 1991). Most of the *Swainsona plagiotropis* sites in the Jerilderie area also have populations of *Swainsona murrayana*. Although not recorded from the mapped area, this species is considered significant for the Hay Plain in its wider context.

(B) Taxa	**Cat./Prior.**	**Habitat**
AIZOACEAE *Zaleya galericulata* subsp. *australis* (Melville) Hj. Eichler	3B/4	Recorded from a *Maireana pyramidata* shrubland (Community 8) during the present survey.
ASTERACEAE *Brachycome exilis* Sond.	3B/4	A *Maireana pyramidata* community (Community 8) on a sand ridge (Leigh & Mulham 1977).
BRASSICACEAE *Cuphonotus humistratus* (F. Muell.) O.E. Schultz	2/3	*Atriplex vesicaria* and *Maireana aphylla* communities (Communities 11 and 21) (Semple 1986).
Menkea australis Lehm.	3B/4	Widespread in northern districts of the riverine plain where it may be locally common (Leigh & Mulham 1977).
Pachymitus cardaminoides (F.Muell.) O.E. Schultz	3B/4	Recorded from 'Zara', north-west of Deniliquin in 1903 and probably overlooked since then (Mulham & Jones 1981).

Table 5 (continued)

B) Taxa	**Cat./Prior.**	**Habitat**
Rorippa eustylis (F. Muell.) L.A.S. Johnson	3B/4	A *Eucalyptus camaldulensis* community (Community 1) (Margules & Partners *et al.* 1990) and a swampy area on a river flat near Deniliquin (Mulham & Jones 1981).
Stenopetalum velutinum F. Muell.	3B/4	Recorded from Wanganella in 1903 (Leigh & Mulham 1977).
CHENOPODIACEAE		
Dysphania littoralis R.Br.	4A/4	*Eucalyptus camaldulensis* woodlands in moist low-lying areas (Community 1) (Mulham & Jones 1981).
Sclerolaena limbata (J.M. Black) Ulbr.	3B/4	*Atriplex vesicaria* shrubland (Community 11) (present survey).
FABACEAE-FABOIDEAE		
Swainsona reticulata J. Black	4B/4	Confined to clay and clay-loam soils in the southern and eastern districts of the riverine plain (Leigh & Mulham 1977).
Swainsona sericea (A. Lee) H. Eichler	4B/4	Confined to clay and clay-loam soils in the southern and eastern districts of the riverine plain (Leigh & Mulham 1977).
FABACEAE-MIMOSOIDEAE		
Acacia pycnantha Benth.	4B/4	Isolated occurrences in the Tocumwal-Berrigan area (Leigh & Mulham 1977), possibly just within the extreme south-eastern corner of the mapped area.
MYRTACEAE		
Eucalyptus porosa F. Muell. ex Miq.	3B/4	A single tree was recorded from *Eucalyptus largiflorens* woodland (Community 2) in an exclosure protected from grazing (present survey). Also recorded from the Moulamein district (Leigh & Mulham 1977).
POLYGONACEAE		
Muehlenbeckia diclina (F. Muell.) Druce	3B/4	Recorded from 'Manfred', south-west of Ivanhoe (Leigh & Mulham 1977) which is outside the mapped area but still on the riverine plain.
PORTULACACEAE		
Calandrinia volubilis Benth.	3A/3	*Atriplex vesicaria* communities (Community 11) (Leigh & Mulham 1977, Semple 1986).

The conservation status of some of the other communities mapped appears to be satisfactory. The central western mallee communities are well represented in a number of nature reserves to the north-east of the mapped area, including Yathong, Round Hill and Nombinnie Nature Reserves. The acquisition of Nombinnie along with Yathong Nature Reserve has consolidated the conservation of the *Eucalyptus socialis–E. dumosa–E. gracilis* association (Benson 1988). The southern mallee outlier, however, between Griffith and Hillston is almost completely cleared and cultivated. Clearing for grazing and cropping has also reduced the distribution of some mallee communities in their eastern most occurrences (Benson 1989). Conservation recommendations for remnant mallee areas include maintaining roadside and fenceline corridors for habitat and erosion control and fencing to exclude stock (Morgan & Terrey 1992). *Eucalyptus intertexta*, a component of the Warranary Hill Woodland Complex (Community 29) in the far north-east of the mapped area is very poorly conserved (Benson 1988). Some *Maireana pyramidata* and *Maireana sedifolia* is conserved within Kinchega and Mungo National Parks although these species remain unconserved on the Hay Plain.

Conservation of species

The conservation status of species on the Hay Plain and south-western New South Wales generally is poor. Forty-four per cent of all vulnerable plants in New South Wales occur on the western slopes and plains (Benson 1989, 1991). This is due to the widespread environmental modification since European settlement and because there are relatively few reserves in these areas compared to the eastern part of the state. Five species that once existed on the Western Plains botanical subdivisions are now extinct while at least ten now only occur interstate (Benson 1989). Seven rare species have been recorded from the Hay Plain while one species, *Ptilotus extenuatus*, is presumed extinct (Briggs & Leigh 1988). Species of particular conservation significance within the mapped areas are listed in Table 5.

More knowledge of the population biology of these restricted, threatened and rare species is needed, starting with surveying their distributions and protecting populations in reserves where possible.

Conservation recommendations

The clearing of land for irrigation and cropping and the prevention of regeneration of native species due to grazing pressure are the major factors contributing to vegetation loss on the Hay Plain. In such an altered area, any relatively intact remnants of natural vegetation need to be carefully managed. No further clearing should be permitted without regional assessment. The regeneration of perennial species is essential to achieve landscape stability within the pastoral areas (Morgan & Terrey 1992).

It is clear that high stocking rates and grazing pressure from other introduced and native herbivores will continue to be most detrimental to the survival of the remaining natural vegetation. The prevention of regeneration in many communities by grazing pressure has serious ramifications for their future survival. To ensure the long-term stability of the vegetation and soil, management should aim to utilise the annual element of the pasture, while maintaining the perennial component (Dalton 1988). Continuing irrigation practices and tree clearing may leave riparian and floodplain vegetation vulnerable to dieback from rising salinity.

Options for conserving native vegetation range from the gazetting of fully managed national parks and nature reserves in appropriate areas, to the more immediate action of vegetation retention and protection by individual land managers through altered management practices. Because of the remnant nature of native vegetation on the Hay Plain today, carefully chosen and managed reserves should be incorporated into any future land management plans for the area. Conservation programs will require the acquisition and establishment of reserves in which there is complete eradication of all stock and feral herbivores, and control of native herbivores. The concept of individual custodianship of natural resources may be the key to the future survival of remnant vegetation communities and habitats in much of south-western New South Wales.

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APPENDIX 1

Species list for communities identified on the Booligal, Hay and Deniliquin–Bendigo 1:250 000 map sheets. Key to communities on pages 22–23.

Key

a Leigh, J.H. and Mulham, W.E. (1977) Vascular plants of the Riverine Plain of New South Wales with notes on distribution and pastoral use. *Telopea* 1(4): 225–293 and Mulham, W.E. and Jones, D.E. (1981) Vascular plants of the Riverine Plain of New South Wales – supplementary list. *Telopea* 2(2): 197–213.

b Cunningham, G.M. and Milthorpe, P.L. (1981) The vascular plants of five exclosures in western New South Wales. *Cunninghamia* 1(1): 23–34. *(Soil Conservation Service of New South Wales experimental exclosures 'Trida', 'Micabil', 'Sayers Lake' and 'Booberoi').*

c Semple, W.S. (1986) Plant species lists from four exclosure sites in the Hay district of south-western New South Wales. *Cunninghamia* 1(4): 491–502. *(Soil Conservation Service of New South Wales experimental exclosures 'Jim Barren', 'One Tree', 'Paradise' and 'Tchelery').*

d Pressey, R.L., Bell, F.C., Barker, J., Rundle, A.S. & Belcher, C.A. (1984) *Bio-physical features of the Lachlan-Murrumbidgee confluence, south-western New South Wales.* (NSW National Parks & Wildlife Service). *(Great Cumbung Swamp area).*

e Margules and Partners Pty Ltd, P. & J. Smith Ecological Consultants and Department of Conservation Forests and Lands Victoria (1990) *Riparian vegetation of the River Murray* (Murray-Darling Basin Commission). *(Murray River Section 4).*

[] synonymous names
* exotic
# extension of known range in NSW (specimen held National Herbarium of NSW).
! new record for NSW (unsubstantiated).
@ ROTAP listed (Briggs & Leigh 1988).
% western division plants with restricted distribution (Pressey *et al.* 1990).

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
PTERIDOPHYTES						
Aspleniaceae						
Pleurosorus subglandulosus		29				
Azollaceae						
Azolla filiculoides						de
A. filiculoides var. *rubra*						a
A. pinnata						d

Dennstaedtiaceae						
Pteridium esculentum		16				
Isoetaceae						
Isoetes muelleri						a
Marsileaceae						
Marsilea angustifolia						a
M. drummondii	1	2 25 28		11 12 18 21	13 23 26	d
Ophioglossaceae						
Ophioglossum lusitanicum						
Pteridaceae						
Pteris tremula						a
Sinopteridaceae						
Cheilanthes austrotenuifolia [*C. sieberi* subsp. *tenuifolia*]		29				
C. sieberi subsp. *sieberi* [*C. tenuifolia* subsp. *sieberi*]						a
GYMNOSPERMS						
Cupressaceae						
Callitris glaucophylla		4 16 17 24 27 29	3d	8 11		
C. gracilis subsp. *murrayensis* [*C. preissii* subsp. *murrayensis*]		16 24				e
ANGIOSPERMS-DICOTYLEDONS						
Aizoaceae						
Disphyma crassifolium subsp. *clavellatum* [*D. clavellatum*]				8 11 12 21	13	
**Galenia pubescens*						a
Glinus lotoides	1	2 28				
**Mesembryanthemum crystallinum*		2		8		
**M. nodiflorum*						a
Sarcozona praecox						ac
Tetragonia tetragonoides						abc
%*Zaleya galericulata* subsp. *australis*				8		

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Amaranthaceae						
Alternanthera angustifolia						
A. denticulata	1	2 25 28		11 18		
A. nodiflora		2				
**A. pungens*						a
**Amaranthus albus*						a
**A. hybridus*						a
A. macrocarpus	1	2 28				
**A. retroflexus*						a
**A. viridus*						a
Ptilotus atriplicifolius var. *atriplicifolius*						a
P. erubescens						a
P. gaudichaudii var. *parviflorus*		4 16				
P. macrocephalus						a
P. nobilis		25				
P. polystachyus var. *polystachyus*		25				
P. semilanatus						a
P. spathulatus		4 16 25 29				
Anacardiaceae						
**Schinus areira*						ad
Apiaceae						
**Ammi majus*						a
**Apium leptophyllum*						a
Daucus glochidiatus		25 27 28		8 11 12 21		
Eryngium plantagineum				21		
E. rostratum						a
**Foeniculum vulgare*						a
Hydrocotyle laxiflora						a
Asteraceae						
**Acroptilon repens*						a
Actinobole uliginosum		4 16 29	3b			
Angianthus brachypappus				19		
A. tomentosus						b

**Arctium minus*					a
**Arctotheca calendula*	1	2 24 25	11 18 21 22		
**Artemisia arborescens*		24			
**Aster subulatus*					abe
**Bidens pilosa*			21		
**B. subalternans*					a
Brachycome basaltica var. *gracilis*					ad
B. species *B*					ac
B. ciliaris var. *ciliaris*		29			
B. ciliaris var. *lanuginosa*					b
B. curvicarpa					ac
%*B. exilis*					a
B. goniocarpa					ab
B. heterodonta var. *heterodonta*					ab
B. lineariloba		25 29	8 11 21		
@*B. papillosa*			21		ac
B. readeri					a
Bracteantha bracteata [*Helichrysum bracteatum*]					e
**Calendula palaestina*					a
Calocephalus citreus					ab
C. sonderi		4 16	8 11 12 19 21 22	13 26	
Calotis anthemoides		25			
C. cuneifolia					a
C. cymbacantha					b
C. hispidula	1	4 16 25 29			
C. lappulacea					a
C. plumulifera					b
C. scabiosifolia var. *integrifolia*					b
C. scabiosifolia var. *scabiosifolia*		25	11 21		
C. scapigera		2			
**Carduus pycnocephalus*					a
**C. tenuiflorus*					ace
**Carthamus lanatus*					abc
Cassinia arcuata					a
**Centaurea calcitrapa*					a
**C. melitensis*		2	21		
Centipeda cunninghamii	1	2 25 28	8 18	23	d
C. minima					abde
C. thespidioides					abc
**Chondrilla juncea*	1				

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Asteraceae (cont'd)						
**Chrysanthemoides monilifera*						a
Chrysocephalum apiculatum		25	3b	21 22		
[*Helichrysum apiculatum*]						
Chthonocephalus pseudevax						ab
**Cichorium intybus*						a
**Cirsium vulgare*	1	2 16 25 27		11 18 21	13 23	d
**Conyza albida*						acd
**C. bonariensis*	1					
Cotula australis	1	25				
**C. bipinnata*	1	25		11 19 21 22		
**C. coronopifolia*					23	
!*Craspedia glauca*						e
!*C. uniflora*						a
C. variabilis		29				
Cymbonotus lawsonianus						e
C. preissianus						a
**Cynara cardunculus*						a
Eclipta platyglossa		2 28				
Epaltes australis						ae
E. cunninghamii						ab
Eriochlamys behrii						ac
**Gnaphalium coarctatum*						a
G. gymnocephalum						ae
G. sphaericum						bce
Gnephosis arachnoidea						b
**Hedypnois rhagadioloides* subsp. *cretica*		4 16 25		21		
Helichrysum leucopsideum						e
H. rutidolepis						a
!*H. semipapposum*						a
Hyalosperma glutinosum subsp. *glutinosum*						ac
[*Helipterum hyalospermum*]						
H. praecox						ac
[*Helipterum praecox*]						
H. semisterile		25	3b			
[*Helipterum jessenii*]						

**Hypochaeris glabra*		25 29		11 21		
**H. radicata*		4 16		21		
Isoetopsis graminifolia						ab
Ixiolaena leptolepis				8 11 21		
I. tomentosa		2 16 24 25		11 21 22	13	
**Lactuca saligna*						ae
**L. serriola*						bce
**Leontodon taraxacoides*						ae
#*Leptorhynchos elongatus*		25				
L. panaetioides		24		11 21		
L. squamatus						a
Leucochrysum molle [*Helipterum molle*]				21		
Microseris lanceolata						ac
Millotia myosotidifolia		29				
**M. perpusilla*						a
Minuria cunninghamii			3d	8 11 12 19 21 22		
M. denticulata						abc
M. integerrima						abc
M. leptophylla		25 29				
Myriocephalus rhizocephalus		25	3d	18 19 21		
M. stuartii						c
Olearia pimeleoides			3b 3d			
**Onopordum acanthium*						a
**O. acaulon*						ac
**Picris echioides*						ace
**P. hieracioides*						d
Podolepis canescens						a
P. muelleri				11 21		
Podospermum resedifolium* [Scorzonera laciniata*]				11		
Pogonolepis muelleriana						ab
P. stricta						c
Pseudognaphalium luteo-album	1					
Pycnosorus chrysanthus [*Craspedia chrysantha*]						ab
P. globosus [*Craspedia globosa*]						ac
P. pleiocephalus [*Craspedia pleiocephala*]		4 16 25 29		8 21		

Botanical Name	**Community**					**Other Records**
	Forest	**Woodland**	**Mallee**	**Shrubland**	**Grassland**	
Asteraceae (cont'd)						
**Reichardia tingitana*						a
Rhodanthe corymbiflora		2 4 16 25 29		8 11 18 19 21 22	26	
[*Helipterum corymbiflorum*]						
R. diffusa						c
[*Helipterum diffusum*]						
R. floribunda		4 16 25 29		8 11 21		
[*Helipterum floribundum*]						
R. moschata						abc
[*Helipterum moschatum*]						
R. polygalifolia						ab
[*Helipterum polygalifolium*]						
R. pygmaea		4 16 25		11 21		
[*Helipterum pygmaeum*]						
R. stuartiana						a
[*Helipterum stuartianum*]						
R. uniflora		4 16				
**Scolymus hispanicus*						a
Senecio cunninghamii var. *cunninghamii*				18	23	d
S. glossanthus		25		11 21		
S. hispidulus var. *dissectus*						a
S. lautus subsp. *dissectifolius*				11 21		
S. linearifolius						a
S. platylepis						a
S. quadridentatus	1	2		21		
S. runcinifolius	1			18 21		
Sigesbeckia orientalis subsp. *orientalis*						a
**Silybum marianum*						a
Solenogyne bellioides						a
S. dominii						a
**Sonchus asper* subsp. *glaucescens*						d
!*S. hydrophilus*						e
**S. oleraceus*	1	2 25 28 29		11 21	26	
Stuartina muelleri						ab
**Taraxacum officinale*						a
**Tragopogon porrifolius*						a
Triptilodiscus pygmaeus		25 29				
[*Helipterum australe*]						

**Urospermum picroides*						c
Vittadinia cervicularis var. *cervicularis*						be
V. condyloides						c
V. cuneata var. *cuneata*		25		11		
V. cuneata var. *hirsuta*		25				
V. dissecta						e
V. gracilis		2 16 27 28			26	
V. pterochaeta		25				
V. tenuissima						a
**Xanthium ambrosioides*						a
**X. occidentale*	1					ad
**X. orientale*						a
**X. spinosum*	1	25 28		8 12 18 19	13	
Bignoniaceae						
Pandorea pandorana		29				
Boraginaceae						
**Amsinckia intermedia*						a
**Anchusa arvensis*						a
**Buglossoides arvensis*						a
Cynoglossum australe						a
C. suaveolens						a
**Echium plantagineum*	1	2 4 16 24 25 27 28		8 11 18 21 22	26	
**Heliotropium curassavicum*						a
**H. europaeum*	1	16 25 27		8 21		
**H. supinum*		2				
Omphalolappula concava		25		8		
Plagiobothrys elachanthus						a
P. plurisepaleus						bc
Brassicaceae						
**Alyssum linifolium*		25		8		
Arabidella eremigena						a
A. nasturtium						ac
A. trisecta						b
**Brassica juncea*						a
**B. rapa* subsp. *silvestris*			3b	21	26	
**B. tournefortii*		4 16				
**Capsella bursa-pastoris*						ace

Botanical Name	Community Forest	Woodland	Mallee	Shrubland	Grassland	Other Records
**Cardaria draba*						a
**Carrichtera annua*		29		11 18 19		
**Coronopus didymus*						a
%Cuphonotus humistratus						bc
**Diplotaxis tenuifolia*						a
Geococcus pusillus						a
Harmsiodoxa blennodioides		29				
H. brevipes var. *brevipes*						c
**Hirschfeldia incana*						a
**Lepidium africanum*		25				
L. fasciculatum		28				
@L. monoplocoides				8		ae
L. papillosum		29				
L. pseudohyssopifolium		2 16 25 27		21		
!L. rotundum						b
L. sagittulatum						bc
%Menkea australis						ac
%Pachymitus cardaminoides						a
Phlegmatospermum cochlearinum						ab
**Rapistrum rugosum*	1					
**Raphanus raphanistrum*						a
%Rorippa eustylis						ae
R. laciniata						ade
**R. palustris*						ae
**Sinapis alba*						a
**Sisymbrium altissimum*						b
**S. erysimoides*	1	28		19 21		
**S. irio*	1	25				
**S. officinale*						a
**S. orientale*		25 29				
Stenopetalum lineare						e
%S. velutinum						a
Callitrichaceae						
Callitriche cyclocarpa						e
C. sonderi						e
**C. stagnalis*						ae

Campanulaceae					
Wahlenbergia communis					abce
W. fluminalis					acde
W. gracilenta					c
W. gracilis	1	25			abce
W. luteola		25			
W. stricta subsp. *alterna*		4			
W. stricta subsp. *stricta*		4 16 27 29		11	
Cannabaceae					
**Cannabis sativa*					a
Capparidaceae					
Apophyllum anomalum		28			
Caryophyllaceae					
**Cerastium glomeratum*					ae
**Moenchia erecta*					a
**Petrorhagia velutina*					ae
**Polycarpon tetraphyllum*					a
Scleranthus minusculus	1				
**Silene gallica*					a
**Spergula pentandra*					a
**Spergularia diandra*					ac
**S. rubra*		2 4 16 25 28	3d	8 11 18 21 22	
Stellaria angustifolia					ae
**S. media*	1				
**Vaccaria pyramidata*					a
Casuarinaceae					
Allocasuarina luehmannii		16 17 24			
Casuarina cristata		16			
C. obesa					e
C. pauper		4 16 17 28 29	3d	8p	
C. pauper/C. cristata intergrades		28			
Chenopodiaceae					
Atriplex angulata					ab
A. conduplicata				8	
A. eardleyae		16 27 28		21	
A. holocarpa				11	

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Chenopodiaceae (cont'd)						
Atriplex infrequens						b
A. intermedia						b
A. leptocarpa		2 16 25 27		8 11 12 18 21		
A. lindleyi		2 28		8 8p 11 12 18 19 21	13	
A. nummularia		2 16 25 27		8 11 19	13	
A. pseudocampanulata		2 16		8 11 12 18 19 21	13	
A. pumilio						d
A. semibaccata		2 16 25 27 28		8 11 12 18 21		
A. spinibractea						a
A. spongiosa						ab
A. stipitata		25 28	3d	11		
A. suberecta		2		18		
A. vesicaria		2 4 25 28		8 8p 11 12 19 21 22	13	
**Chenopodium album*						a
**C. ambrosioides*						a
C. auricomum						a
C. carinatum						a
C. cristatum						c
C. curvispicatum [*Rhagodia gaudichaudiana*]		16		11		
C. desertorum subsp. *microphyllum*						a
C. melanocarpum						ab
**C. multifidum*						a
**C. murale*		2				
C. nitrariaceum	1	2 16 27 28		8 11 12 18 19	13 26	
C. pumilio	1	2		8		
Dissocarpus biflorus var. *biflorus*		4	3d	8 11 19	13	
D. biflorus var. *cephalocarpus*						b
D. paradoxus		4 27	3d	8 8p 11 19 21	26	
%*Dysphania littoralis*						a
Einadia hastata						ae
E. nutans	1	2 16 25 27 28 29		8 11 12 19 21	13	
E. polygonoides						a
E. trigonos						a
Enchylaena tomentosa		2 4 16 25 27 28	3d	8 11 19		

Maireana aphylla		4 16 25 27		8 11 19 21 22	13 26	
M. appressa				8		
M. brevifolia		4 16				
@*M. cheelii*						ac
M. coronata		25				
M. decalvans		2 16 25 27 28		8 11 21	26	
M. enchylaenoides						ae
M. excavata						a
M. georgei		28		8 21		
M. humillima		4 16				
M. lobiflora		25				
M. microcarpa						ac
M. microphylla						ab
M. pentagona		2 16 25 27		11 21 22	26	
M. pyramidata		2 4 16 27 28	3d	8 8p 11 12 19		
M. sclerolaenoides		25 27				
M. sedifolia		4 27	3d	8 8p		
#*M. turbinata*		25		8		
Malacocera tricornis		2 16 27		8 8p 11 12 18 19 21	13	
Osteocarpum acropterum var. *deminuta* [*Babbagia acroptera*]		28		8 8p 11 12 21		
!*O. saluginosum* [*Threlkeldia saluginosa*]						ab
Rhagodia spinescens	1	2 4 16 17 25 27 28	3d	8 8p 11 12 19 21	13 26	
R. ulicina						a
Salsola kali		2 16 27 28		8 11 19 21	26	
Scleroblitum atriplicinum						ac
Sclerolaena articulata						b
S. bicornis var. *bicornis*		2 28	3b 3d	8 11 12 19 21		
S. bicornis var. *horrida*		25				
S. birchii		28				
S. brachyptera		16 25 27 28		8 8p 11 12 19 21 22		
S. calcarata						b
S. decurrens						ab
S. diacantha				21		
S. divaricata				8 11 21		
S. eriacantha						b
S. intricata		2		8 11 12		
S. lanicuspis						ab
%*S. limbata*				11		

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Chenopodiaceae (cont'd)						
Sclerolaena muricata	1	2 16 24 25 27 28		11 12 18 19 21 22	13 26	
S. muricata var. *muricata*				11 21		
S. muricata var. *semiglabra*		16 24 25				
S. muricata var. *villosa*		2		11 21		
S. obliquicuspis						bd
S. parallelicuspis						a
S. patenticuspis						bc
S. stelligera		16 25 27	3d	11 12 18 21	26	
S. tricuspis		2 16 25 27 28		8 8p 11 12 18 19 21 22	13	
S. uniflora						b
S. ventricosa						b
Sclerostegia tenuis				11 12 19	13	
Clusiaceae						
Hypericum gramineum						e
H. japonicum						a
**H. perforatum*						a
Convolvulaceae						
Calystegia sepium						a
**Convolvulus arvensis*		2 27		8		
C. erubescens	1	25 28		8 11 12 18 21	13	
Cressa cretica				11		
Evolvulus alsinoides		2				
Wilsonia rotundifolia						a
Crassulaceae						
Crassula colorata var. *acuminata*		16 25 29		8 11 19 21		
C. helmsii						a
C. decumbens var. *decumbens*		4 16 25 29	3d			
C. peduncularis						ae
C. sieberiana						abce
Cucurbitaceae						
**Citrullus lanatus* var. *lanatus*						abc
**Cucumis myriocarpus*		25 27 28		19	26	

**Ecballium elaterium*						a
Zehneria micrantha						a
Dilleniaceae						
Hibbertia obtusifolia						a
Droseraceae						
Drosera glanduligera						a
D. peltata						a
Elatinaceae						
Bergia trimera						a
**Elatine gratioloides*						a
Euphorbiaceae						
Beyeria viscosa		29				
Chamaesyce dallachyana						d
C. drummondii	1	2 16 25 27 28		21	26	
**Chrozophora tinctoria*						a
E. eremophila						abc
**E. peplus*						a
E. planiticola		27		21	26	
Phyllanthus lacunarius						a
Fabaceae-Caesalpinoideae						
Senna artemisioides subsp. *circinnata* [*Cassia circinnata*]						a
S. artemisioides nothosubsp. *coriacea* [*Cassia eremophila* var. *coriacea*]		24				
S. artemisioides subsp. *filifolia* [*Cassia eremophila* var. *eremophila*]		4 24	3d			
S. artemisioides subsp. *petiolaris* [*Cassia eremophila* var. *platypoda*]		16	3d			
S. artemisioides subsp. *zygophylla* [*Cassia eremophila* var. *zygophylla*]		16 24 25				
S. barclayana						a
Fabaceae-Faboideae						
**Alhagi maurorum*						a
Bossiaea buxifolia						a
**Chamaecytisus palmensis*						a

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Fabaceae-Faboideae (cont'd)						
Daviesia mimosoides						a
Dillwynia cinerascens	1					
D. sericea						a
Eutaxia diffusa						a
E. microphylla						ae
**Genista linifolia*						a
Glycine clandestina						a
G. tabacina						a
Glycyrrhiza acanthocarpa						ae
Lotus australis						a
**L. corniculatis*						a
L. cruentus						abc
**Medicago laciniata*		29				
**M. minima*		29				
**M. polymorpha*	1	2 16 24 25 27		8 11 18 21	26	
**M. praecox*	1	2 4 16 24 25		8 11 12 19 21 22	13 26	
**M. sativa*						ab
**M. truncatula*		2 4 16 24 25 28		8 11 21	26	
!**Melilotus alba*						a
**M. indica*						ad
**Prosopis glandulosa* var. *glandulosa*						a
**P. juliflora*						a
Psoralea cinerea						a
P. tenax						ae
Pultenaea largiflorens						a
Swainsona burkittii						b
@*S. murrayana*		25		11 21		ab
!%*S. reticulata*						a
[*S. oroboides* subsp. *reticulata*]						
S. phacoides						ae
@*S. plagiotropis*						a
S. procumbens		25		11 21		
%*S. sericea*						a
[*S. oroboides* subsp. *sericea*]						
S. swainsonioides						ab

Templetonia egena						a
**Trifolium angustifolium*						ae
**T. arvense*	1					
**T. campestre*						ae
**T. cernuum*						ae
**T. dubium*						e
**T. glomeratum*						abce
**T. repens*						e
**T. striatum*		25 29				
**T. subterraneum*		25		18		
**T. tomentosum*						abce
**Vicia hirsuta*						ae
**V. monantha* subsp. *triflora*						ab
**V. sativa* subsp. *sativa*						ae
Fabaceae-Mimosoideae						
Acacia acinacea	1	16 24				
A. aneura						a
A. brachybotrya		16 24				
A. colletioides			3d			
A. dealbata	1					e
A. deanei						a
A. decora						a
**A. farnesiana*						a
A. hakeoides		16 24 28				
A. homalophylla		16 17				
A. implexa						a
A. ligulata		4 16 27			26	
A. lineata						a
A. loderi						ab
A. melvillei		4 16 17	3d	11		
A. montana						a
A. oswaldii		16 17 24 28				
A. pendula		16 17 25 27 28		21	26	
%*A. pycnantha*						a
A. rigens		2 16 24				
A. salicina	1	2 16				
A. stenophylla	1	2				
A. victoriae		4 16	3d			
A. wilhelmiana			3b 3d			

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Frankeniaceae						
Frankenia connata				11 21		
F. crispa						b
F. latior						a
F. serpyllifolia						b
Fumariaceae						
**Fumaria bastardii*						a
**F. capreolata* subsp. *capreolata*						ae
**F. densiflora*						a
**F. muralis* subsp. *muralis*						ae
Gentianaceae						
Centaurium spicatum						abc
**C. tenuiflorum*						b
**Cicendia quadrangularis*						a
Sebaea ovata						a
Geraniaceae						
**Erodium botrys*		25				
**E. brachycarpum*						a
**E. cicutarium*		2 24 25		8 11 19 21	26	
E. crinitum	1	2 4 16 25 28 29	3b	11 12 18 21	13 26	
E. cynogorum subsp. *glandulosum*						b
**E. malacoides*				21		
**E. moschatum*		2 25		11 19 21	26	
Geranium retrorsum						ae
G. solanderi var. *solanderi*	1			21	26	
Goodeniaceae						
Goodenia cycloptera						b
G. fascicularis		25		11		
G. glauca						acde
G. gracilis				11		
G. heteromera						ab

G. pinnatifida		4 16 25 29	21		
G. pusilliflora		4 16 25 29	8 11 21		
!*G. subintegra*					a
Velleia paradoxa		4 29			
Haloragaceae					
Haloragis aspera		2			
H. glauca		25			
H. heterophylla					ab
Myriophyllum crispatum					ade
M. verrucosum					ade
Lamiaceae					
Ajuga australis					a
**Lamium amplexicaule*					ae
**Marrubium vulgare*		2 24 25 27		26	
Mentha australis		2			
M. diemenica					a
**M. pulegium*					a
M. satureoides					a
**Salvia reflexa*					a
**S. verbenaca*					a
**Stachys arvensis*					ad
Teucrium racemosum		2 27 28			
Linaceae					
Linum marginale					ab
**L. usitatissimum*					a
Lobeliaceae					
Isotoma fluviatilis					a
!*Lobelia pratioides*					e
Pratia concolor	1	2 25		23	d
P. darlingensis					a
Loranthaceae					
Amyema linophyllum subsp. *orientale*					ae
A. miquelii					ae
A. miraculosum subsp. *boormanii*		16 28			

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Loranthaceae (cont'd)						
Amyema linophyllum. pendulum	1					
A. preissii		2 16				
A. quandang var. *quandang*		25 28				
Lysiana exocarpi subsp. *exocarpi*		2 16				
#*L. exocarpi* subsp. *tenuis*			3d			
Lythraceae						
Ammannia multiflora						a
Lythrum hyssopifolia		28				
L. salicaria						a
Malvaceae						
Abutilon halophilum		27		11		
A. otocarpum						c
A. theophrasti						a
Hibiscus brachysiphonius						b
H. trionum						ac
Lavatera plebeia		27			26	
**Malva parviflora*	1	25 27		11 12 21	13 26	
Malvastrum americanum						b
Sida ammophila		2 27		11	26	
S. corrugata		2 16 25 27 28 29		8 8p 11 19 21	26	
S. cunninghamii		4 16 29				
S. fibulifera	1					
S. intricata		25 27		21	26	
S. subspicata						a
S. trichopoda	1	2 16 25 27		11 21	26	
Martyniaceae						
**Ibicella lutea*						a
**Proboscidea louisianica*						a
Menyanthaceae						
Nymphoides crenata						ade

Myoporaceae						
Eremophila bignoniiflora						b
E. debilis		24				
E. deserti						a
E. divaricata						a
E. glabra			3b 3d			
E. longifolia	1	16 25 28		8		
E. maculata						a
E. mitchellii		29				
E. sturtii			3b			
Myoporum montanum						a
M. platycarpum		4	3d			
Myrtaceae						
Callistemon brachyandrus						a
C. sieberi						a
Calytrix tetragona						a
Eucalyptus camaldulensis	1	2			23	d
E. camaldulensis/E. largiflorens hybrids	1					
E. dumosa			3b 3d			
E. gracilis			3b 3d			
E. intertexta		16 29	3d			
E. largiflorens	1	2 16 24	3d	18 19		
E. leucoxylon subsp. *pruinosa*						a
E. leptophylla			3b 3d			
E. melliodora		2 16 24				
E. microcarpa	1	2 16 24				
E. oleosa			3d			
E. populnea subsp. *bimbil*		2 4 16 28	3d			
%*E. porosa*		2				a
E. socialis			3b 3d			
E. vicina		29				
#*Melaleuca lanceolata* subsp. *lanceolata*		2 16				
Nitrariaceae						
Nitraria billardierei	1	2 16 25		8 11 12 19 21 22	13	
Nyctaginaceae						
Boerhavia coccinea		2 16 25 27		11 21	26	

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Oleaceae						
Jasminum lineare		16				
Onagraceae						
Epilobium billardierianum subsp. *cinereum*						ace
E. hirtigerum						de
**Ludwigia peploides* subsp. *montevidensis*						d
**Oenothera affinis*						a
**O. stricta* subsp. *stricta*						a
Oxalidaceae						
Oxalis corniculata s.lat.						bc
O. perennans	1	2 16 25 27 28		8 11 12 18 19 21	13 26	
**O. pes-caprae*		24				
Papaveraceae						
**Argemone ochroleuca* subsp. *ochroleuca*						a
**Papaver hybridum*				8		
**P. somniferum* subsp. *setigerum*						a
Pittosporaceae						
Bursaria spinosa		24				
Pittosporum phylliraeoides		4 16 27 29	3d			
Plantaginaceae						
Plantago cunninghamii				11 21		
**P. coronopus* subsp. *commutata*						a
P. debilis				8		
P. drummondii		25				
P. gaudichaudii						a
**P. lanceolata*						ae
P. turrifera						abc
P. varia						a
Plumbaginaceae						
**Limonium sinuatum*						a

Polygonaceae					
**Acetosa vesicaria*					a
**Acetosella vulgaris*					a
**Emex australis*					a
Muehlenbeckia florulenta	1	2 25	18	13	
%*M. diclina*					a
M. horrida					acd
Persicaria decipiens				23	ade
P. hydropiper					a
P. lapathifolia					a
P. orientalis					ad
P. prostrata					ade
**Polygonum arenastrum*					a
**P. aviculare*		28			
P. decipiens		2			
P. plebeium					ade
Rumex bidens					a
R. brownii	1				
**R. crispus*		2	18 21		d
R. crystallinus					abe
R. dumosus					ac
**R. pulcher* subsp. *pulcher*					a
R. tenax	1	2 25 27 28	11 12 18 21	13 26	
Portulacaceae					
Calandrinia balonensis					b
C. calyptrata					e
C. eremaea		25	11		
**C. menziesii*					a
C. pumila					c
%*C. volubilis*					ac
Portulaca oleracea		27		26	
Primulaceae					
**Anagallis arvensis*		25 28 29			
Proteaceae					
Banksia marginata					a
Hakea leucoptera		16 24 27	8		
H. tephrosperma		16 27 28	8	26	

Botanical Name	Community Forest	Woodland	Mallee	Shrubland	Grassland	Other Records
Ranunculaceae						
Clematis microphylla var. *microphylla*		16				
**Myosurus minimus* var. *australis*	1					
Ranunculus inundatus						ade
R. lappaceus						ade
**R. muricatus*						a
R. pentandrus var. *platycarpus*	1	2 25		11 18 19		
R. pumilio var. *politus*		25				
R. pumilio var. *pumilio*	1					
**R. sceleratus*					23	ade
R. sessiliflorus var. *sessiliflorus*						e
R. undosus						ade
Resedaceae						
**Reseda luteola*						a
Rosaceae						
Acaena novae-zelandiae						a
Aphanes australiana						a
**Rosa canina*						a
**R. rubiginosa*						ae
**Sanguisorba minor* subsp. *muricata*						a
Rubiaceae						
Asperula conferta		25				
A. cunninghamii						b
A. gemella		25		18		
**Galium aparine*						ae
**G. murale*						a
Rutaceae						
Flindersia maculosa		4				
Geijera parviflora		4 16 28 29	3d			

Salicaceae					
**Salix babylonica*					e
Santalaceae					
Exocarpos aphyllus		4 16 17 25 28 29	3d	19	
E. cupressiformis					a
E. strictus	1				
Santalum acuminatum		2 16			
S. lanceolatum		16			
Sapindaceae					
Alectryon oleifolius subsp. *canescens*		4 16 17 27 28 29	3d	8 8p 21	
A. oleifolius subsp. *elongatus*		16 27			
Dodonaea bursariifolia					b
D. lobulata		29			
D. viscosa subsp. *angustissima*		4 16 25 27 28	3b 3d		
D. viscosa subsp. *cuneata*					a
Scrophulariaceae					
Glossostigma diandrum					a
Gratiola pedunculata					ad
G. pubescens					a
**Kickxia sieberi*					a
Limosella australis		25		18	
L. curdieana					ac
Mimulus gracilis				18	
M. prostratus					a
**Parentucellia latifolia*		25			
Peplidium foecundum					a
Stemodia florulenta				18	
[*Morgania floribunda*]					
S. glabella					a
[*Morgania glabra*]					
**Verbascum thapsus* subsp. *thaspus*					a
**V. virgatum*					a
**Veronica arvensis*					b
**V. catenata*					a
V. pleibeia					a
**V. peregrina*		25			

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Solanaceae						
**Datura ferox*						a
D. inoxia						a
**D. stramonium*						a
**D. wrightii*						a
Lycium australe						b
**L. ferocissimum*	1	2 16 25 27 28		8 11 18 19 21	26	
**Nicotiana glauca*				18		
N. goodspeedii						b
N. simulans		29				
N. velutina						b
**Solanum elaeagnifolium*						ab
S. ellipticum						a
S. esuriale	1	2 16 25 27 28		8 11 12 18 21	13 26	
**S. linnaeanum*						a
**S. nigrum*	1	2 28		18		
**S. pseudocapsicum*						a
S. rostratum						a
S. simile						a
**S. triflorum*						a
Stackhousiaceae						
Stackhousia monogyna						a
Sterculiaceae						
Brachychiton populneus subsp. *trilobus*		29				
Stylidiaceae						
Levenhookia dubia						a
Thymelaeaceae						
Pimelea curviflora						a
P. microcephala subsp. *microcephala*						a
P. trichostachya						b
P. stricta						a

Urticaceae						
Parietaria debilis		27 29				
Urtica incisa						ac
**U. urens*						abcde
Verbenaceae						
**Phyla nodiflora*						ae
**Verbena bonariensis*						ab
**V. officinalis*		2 28				
**V. supina*				18		
Violaceae						
Viola betonicifolia						a
Zygophyllaceae						
**Tribulus terrestris*		2 27			26	
Zygophyllum ammophilum						a
Z. apiculatum	1					
Z. glaucum		28				
Z. iodocarpum			3d			
Z. ovatum						b
ANGIOSPERMS-MONOCOTYLEDONS						
Alismataceae						
Damasonium minus		2				
**Sagittaria graminea* var. *platyphylla*						a
**S. montevidensis*						a
**S. sagittifolia*						a
Alliaceae						
**Allium triquetrum*						a
**Nothoscordum borbonicum*						a
Amaryllidaceae						
Calostemma purpureum						ab
Crinum flaccidum	1					

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Anthericaceae						
Arthropodium milleflorum						a
A. minus		29				
Dichopogon fimbriatus						a
Thysanotus baueri						bcd
T. patersonii		29				
T. tuberosus						b
Tricoryne elatior						a
Asparagaceae						
**Asparagus officinalis*						ae
Myrsiphyllum asparagoides* [Asparagus asparagoides*]						a
Asphodelaceae						
**Asphodelus fistulosus*						a
Bulbine alata						b
B. bulbosa		25				
B. semibarbata		25 29		8		
Colchicaceae						
Wurmbea dioica subsp. *dioica*		25				
Cyperaceae						
Bolboschoenus fluviatilis [*Scirpus fluviatilis*]						a
Carex appressa	1					
C. bichenoviana						a
C. inversa		25				
C. tereticaulis						a
Cyperus bifax						a
C. concinnus						a
C. difformis						a
**C. eragrostis*						ae
C. exaltatus						ae
C. gunnii						e

C. gymnocaulos			23	ade
C. pygmaeus				ae
C. victoriensis				a
Eleocharis acuta		18	23	d
@*E. obicis*		18	13	b
E. pallens	2 25	12	13 26	
E. plana				b
E. pusilla				ade
E. sphacelata				ad
Fimbristylis aestivalis				a
F. dichotoma				ab
F. velata				a
Isolepis australiensis				a
[*Scirpus australiensis*]				
I. congrua				a
[*Scirpus congruus*]				
I. hookeriana				a
[*Scirpus hookeranus*]				
**I. hystrix*				a
[**Scirpus hystrix*]				
I. victoriensis				a
[*Scirpus victoriensis*]				
Lipocarpha microcephala				a
Schoenus apogon				a
Eriocaulaceae				
@*Eriocaulon australasicum*				a
Hydatellaceae				
Trithuria submersa				a
Hydrocharitaceae				
**Egeria densa*				a
**Elodea canadensis*				a
Hydrilla verticillata				a
Ottelia ovalifolia				a
Vallisneria gigantea			23	ad
Hypoxidaceae				
Hypoxis glabella var. *glabella*	25	12 19 21		
H. hygrometrica				c

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Iridaceae						
**Gynandriris setifolia*						a
**Homeria flaccida*						a
**Romulea flava*						a
**R. minutiflora*		25				
**R. rosea* var. *australis*		25				
Juncaceae						
**Juncus acutus*						ae
J. amabilis						ae
J. aridicola	1				13	
**J. articulatus*					23	ade
J. bufonius						abc
**J. capitatus*						a
J. flavidus		25		12 18 21	13 23	d
J. holoschoenus						a
J. homalocaulis						a
J. ingens	1					
J. pallidus						a
J. radula		25		11 18 21		
J. semisolidus				18		
J. subsecundus						a
J. usitatus						a
Juncaginaceae						
Triglochin calcitrapa						ab
T. hexagona						a
T. procera						ade
T. turrifera						a
Lemnaceae						
Spirodela pusilla						a
Lomandraceae						
Lomandra effusa			3b 3d			

L. filiformis subsp. *coriacea*					a
L. leucocephala subsp. *robusta*					a
L. multiflora					a
Najadaceae					
Najas marina					a
N. tenuifolia					a
Orchidaceae					
Caladenia carnea					a
C. dilatata var. *dilatata*					a
Diuris pedunculata					a
Microtis uniflora					a
Prasophyllum fuscum					a
P. patens					a
Pterostylis mutica					a
Phormiaceae					
Dianella longifolia					abe
Poaceae					
Agrostis avenacea	1	2 16 27		8 11 19 21	
**Aira cupaniana*		25			
**Alopecurus geniculatus*		2		18	
Amphibromus neesii					ab
A. nervosus					ce
A. whitei					a
Aristida calycina var. *praealta*					a
A. behriana		27		11 19	
A. jerichoensis subsp. *subspinulifera*					a
Astrebla lappacea					a
A. pectinata					b
**Avena barbata*					e
**A. fatua*		2 16 25 27 28	3d	8 8p 11 12 18 19 21 22 26	
**A. sativa*				11	
Bothriochloa macra					a
Brachiaria milliiformis					b
**Briza maxima*					a
**B. minor*		25			

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Poaceae (cont'd)						
Bromus alopecuroides						a
B. arenarius				11	26	
**B. catharticus*						ace
[**B. unioloides*]						
**B. diandrus*				11 21 22		
**B. hordeaceus*						a
**B. madritensis*		2 4 16 25 27		11 21 22	26	
**B. molliformis*				11		
**B. rubens*				21		
**Cenchrus incertus*						a
**C. longispinus*						a
**Chloris gayana*						a
C. truncata		2 27		11 21 22	26	
C. ventricosa						a
Cynodon dactylon		28				
Dactyloctenium radulans						ac
Danthonia auriculata						ac
D. caespitosa	1	2 4 16 24 25 27 28	3d	8 8p 11 12 18 19 21 22	13 26	
D. duttoniana						ae
D. eriantha					26	
D. linkii var. *fulva*				21		
D. setacea		25				
Deyeuxia quadriseta						ae
Dichelachne micrantha						a
Digitaria ammophila						ae
D. brownii						a
**D. ciliaris*						a
D. coenicola						ab
D. divaricatissima						ab
**D. sanguinalis*						a
Diplachne fusca						abc
D. muelleri						b
Echinochloa colona						ae
**E. crus-galli*				11		
**E. microstachya*						a

**E. oryzoides*					a
**Ehrharta calycina*					a
**E. longiflora*					ae
**Eleusine tristachya*					a
Elymus scaber					abe
[*Agropyron scabrum*]					
**Elytrigia repens*					e
Enneapogon avenaceus		2 27			
E. nigricans		27			
E. polyphyllus					a
Enteropogon acicularis	1	2 16 25 27 28	8 18 21	26	
Eragrostis australasica	1	2 25 28	8 11 12 18 19 21	13 26	
E. brownii					a
**E. cilianensis*		16 27		26	
**E. curvula*					a
E. desertorum					a
E. dielsii			8p		
E. elongata					ae
E. eriopoda					ab
E. lacunaria		2 16			
E. molybdea					c
E. parviflora		25	8		
**E. minor*					a
E. setifolia			21		
Eriochloa australiensis					ab
E. crebra					ac
E. pseudoacrotricha					abc
Eulalia fulva					a
Glyceria australis					a
**G. maxima*					a
**Holcus lanatus*					a
Homopholis proluta			8p		
[*Panicum prolutum*]					
**Hordeum glaucum*		25			
**H. hystrix*		16 27	12 19 21		
**H. leporinum*	1	2 4 16 17 24 25 28	8 8p 11 12 18 19 21 22	13 23 26	d
**H. marinum*					ace
Iseilema membranaceum					a
I. vaginiflorum					b
**Lamarckia aurea*		25	8 11		

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Poaceae (cont'd)						
Leptochloa digitata				19		
**Lolium perenne*	1	2 16 24 25		11 18 19 21 22	26	
**L. rigidum*					26	
**Lophochloa cristata*						b
**L. pumila*						b
**Oryzopsis miliacea*						a
**Panicum capillare* var. *capillare*						a
**P. capillare* var. *occidentale*						a
P. coloratum	1					
P. decompositum				8 11		
P. effusum		27				
**P. gilvum*						a
P. queenslandicum var. *queenslandicum*						b
P. laevinode						abc
**Parapholis incurva*						abc
**P. strigosa*						ab
Paspalidium constrictum		2 16				
P. jubiflorum	1					
P. distans						d
**Paspalum dilatatum*						ae
P. distichum					23	e
**Pennisetum villosum*						a
**Pentaschistis airoides*						a
Perotis rara						b
**Phalaris aquatica*						ab
**P. minor*				11 21		
**P. paradoxa*	1	28		11 12 18 19 21	13	
Phragmites australis	1				23	d
**Poa annua*						a
**P. bulbosa*						a
P. fordeana	1	2		11		
P. labillardieri						ae
**P. pratensis*						a
P. sieberana						a

**Polypogon monspeliensis*					23	ade
Pseudoraphis spinescens						ae
Puccinellia stricta						ac
**Rostraria cristata*						ab
**R. pumila*						a
**Schismus barbatus*						abcde
**Setaria geniculata* var. *pauciseta*						a
**S. verticillata*						a
Sporobolus actinocladus						b
S. caroli		25 27		11	26	
S. mitchellii						a
Stipa aristiglumis						a
S. bigeniculata						b
S. blackii						a
S. drummondii		25		11		
S. elegantissima				19		
S. metatoris						e
S. nitida		4 16 25		8 8p		
S. nodosa		2 25		11	26	
S. platychaeta						a
S. scabra subsp. *falcata*		16		8		
S. scabra subsp. *scabra*		27				
Stipa sp.	1	24 28		12 21		
Themeda australis						a
Tragus australianus						abc
Triodia scariosa			3b			
Tripogon loliiformis						ab
Triraphis mollis						ab
**Vulpia bromoides*		25		11		
**V. myuros*		4 16 25		11 21	26	
Pontederiaceae						
**Eichhornia crassipes*						a
Potamogetonaceae						
Potamogeton crispus					23	ad
P. ochreatus						a
P. pectinatus						a
P. perfoliatus						a
P. tricarinatus						ade

Botanical Name	Community					Other Records
	Forest	Woodland	Mallee	Shrubland	Grassland	
Ruppiaceae						
Ruppia maritima						a
R. megacarpa						a
Typhaceae						
Typha domingensis					23	ade
T. orientalis	1	2			23	ade
Zanichelliaceae						
Lepilaena australis						a

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The distribution, abundance and habitat of *Eucalyptus dunnii* (Myrtaceae) (Dunn's White Gum) in New South Wales

J.S. Benson and T.C. Hager

Abstract

Benson, J.S[1] *and Hager, T.C.*[2] *([1] National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, NSW, Australia 2000;* [2] *New South Wales National Parks and Wildlife Service, P.O. Box, 1967, Hurstville, NSW, Australia 2220) 1993. The distribution and abundance of* Eucalyptus dunnii *(Myrtaceae) Dunn's White Gum) in New South Wales.* Cunninghamia *3(1): 123–145. Eucalyptus dunnii* is a tall, fast growing forest tree restricted to north-eastern NSW and south-eastern Queensland. It is phylogenetically close to *Eucalyptus angophoroides* which has its closest occurrences 700 km to the south. *E. dunnii* is a nationally listed rare species. In NSW it has a total population estimated to be 82,000 covering 800 hectares, scattered over 10 locations. The largest populations occur on the Koreelah and Tooloom Ranges near Urbenville, while substantial populations are present 140 km to the south on the ranges inland from Coffs Harbour (several small populations are also present in Queensland). Eighty-two per cent of the area containing *E. dunnii* in NSW is located in state forest and six per cent is protected in conservation reserves. *E. dunnii* is confined to rich basaltic or alluvial soils and mostly grows on the margins of rainforest. A consistent suite of associate plant species is present at most locations, varying due to fire frequency or logging history. It seeds in summer, which coincides with the bushfire season in the region. Extensive logging over the last few decades has led to the dominance (86%) of trees with dbh < 0.5 m. Relatively few large, old trees remain. Further conservation reserves are required to protect southern and western populations.

Introduction

Eucalyptus dunnii Maiden (Myrtaceae) is a tall, smooth-barked tree with a recorded maximum height of 50 m (Yabbra State Forest) (Forestry Commission of New South Wales 1989a). It has a limited distribution in north-eastern New South Wales and just crosses the border into south-eastern Queensland (Figure 1). *E. dunnii* is currently regarded as a rare species on the national rare or threatened plant list with a conservation status of 3RCa (Briggs and Leigh 1988). This indicates it is distributed over a range exceeding 100 km, is rare but not in danger of extinction and has over 1000 individuals conserved in conservation reserves.

As *E. dunnii* often dominates the forest canopy it has been distinguished as Forest Type No. 51, Dunn's White Gum, on the forest-type maps produced by the Forestry Commission of New South Wales (1989b). Both Benson (1989) and Hager and Benson (1992) also recognise vegetation dominated by *E. dunnii* as a distinct plant community, one of a number of tall open-forest communities occurring on high nutrient soils in the 1100 to 1500 mm rainfall zone in the far north-eastern corner of NSW. Most of these forests have now been cleared for agriculture or logged and most of the remaining unlogged areas are proposed for logging over the next decade.

This paper presents data on the extent of *E. dunnii* on different land tenures; its abundance and size structure at sample sites; its estimated population in 10 geographically distinct locations; and reviews the conservation status of the species. An analysis of the similarities of site floristics is provided.

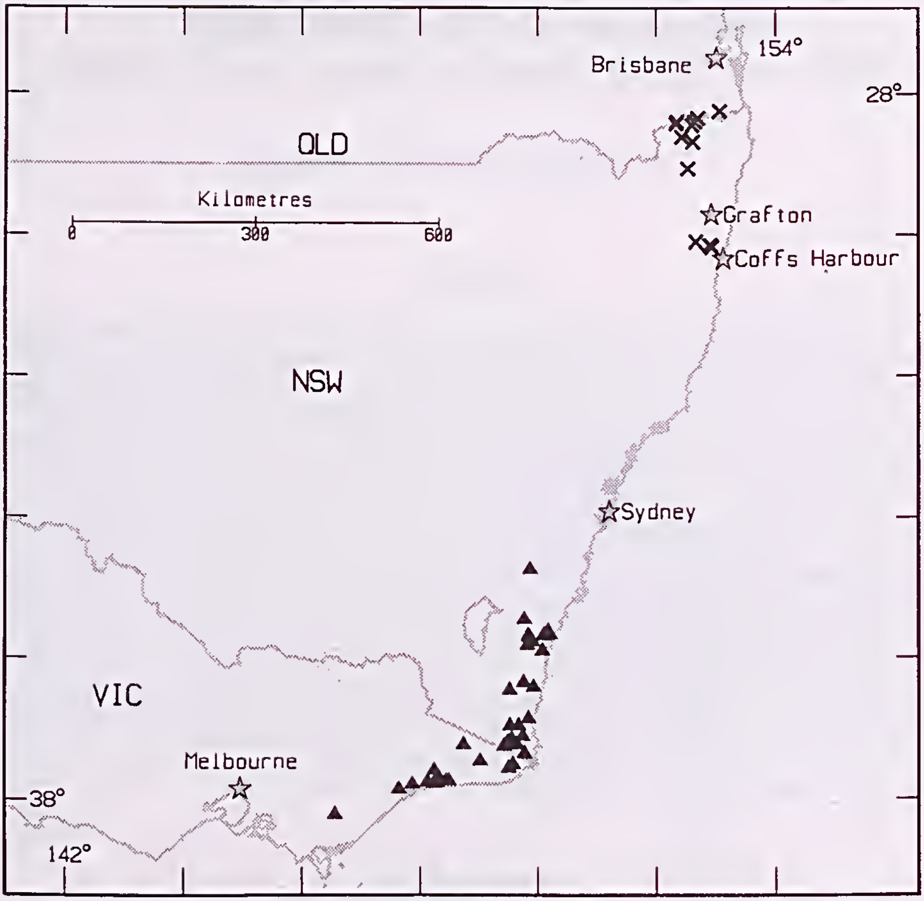

Figure 1. Collections of *Eucalyptus dunnii* (X) and its nearest related species *Eucalyptus angophoroides* (▲) showing their respective geographical ranges in south-eastern Australia. Data from NSW National Herbarium.

Taxonomy

Eucalyptus dunnii has a fibrous, greyish bark on its lower trunk but the bark is smooth above, including the branchlets. Distinguishing morphological features include: juvenile leaves opposite, orbicular to ovate, cordate, dull grey-green (Figure 2); adult leaves narrow-lanceolate, dull green, concolorous; umbellasters 7-flowered; fruit hemispherical or conical or campanulate with exserted valves (Harden 1991).

The occurrence of *E. dunnii* in mixed stands with other smooth-barked eucalypts (gums), such as *E. saligna*, *E. tereticornis* or *E. grandis*, can make field identification of *E. dunnii* difficult. The juvenile leaves and fruit of *E. dunnii* are, however, very distinct from these other associated 'gum' species.

In their phylogenetic classification of *Eucalyptus*, Pryor and Johnson (1971) place *E. dunnii* in Section Maidenaria, Series Viminales and Subseries Bridgesianinae. They propose *E. angophoroides* (a species occurring 700 km to the south of the southern most occurrences of *E. dunnii*) in south-eastern NSW and north-eastern Victoria (Figure 1),

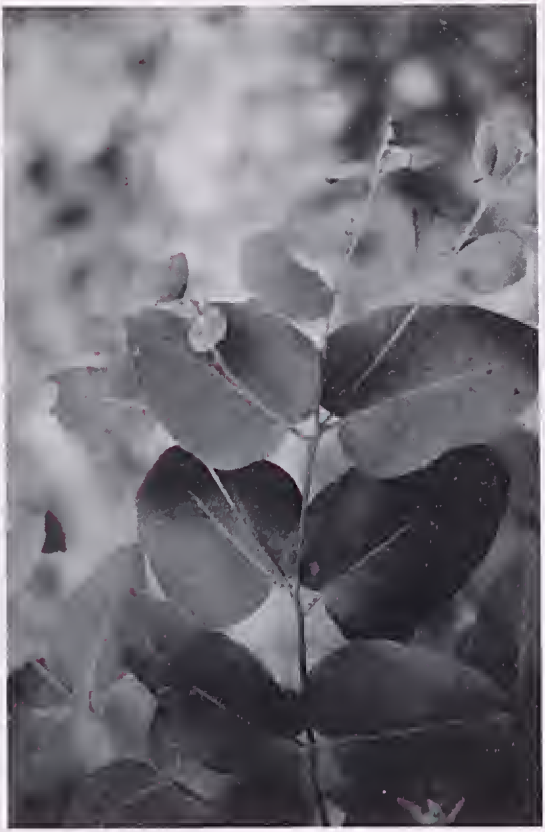

Figure 2. The distinctive orbicular, juvenile foliage of *Eucalyptus dunnii* is a major distinquishing feature of this species.

as being the closest related species. Both subspecies of *E. bridgesiana* (subsp. *bridgesiana* and subsp. *malacoxylon*), which occur on the tablelands west of the *E. dunnii* occurrences, are also suggested as close relatives to *E. dunnii*. This phylogeny is supported by both the weighted character and unweighted character cladistic analyses undertaken by Chappill (1988). These analyses group *E. dunnii* and 18 other taxa into a *E. globulus* clade within the 'Viminales' clade. The analyses suggest that the closest relative to *E. dunnii* is *E. angophoroides* with *E. bridgesiana* subsp. *bridgesiana* and the threatened Victorian species *E. crenulata* also exhibiting strong affinities. All of these last-mentioned species share the characteristic of crenulate juvenile leaves.

Biology and use of timber

Most of the biological research on *E. dunnii* has been carried out on its growth rates in plantations in Brazil and South Africa, reflecting the importance of the species as a source of pulp for paper production in these countries.

Eucalyptus dunnii is one of the fastest growing eucalypts. Oliveira (1988) reports that it, along with *E. viminalis*, outgrew 31 other species of eucalypts during trials at Tres Barras, Santa Catarina in Brazil at an altitude of 775 m. Impressive growth rates have also been achieved in the Natal midlands, South Africa (Nixon and Hagedorn 1984).

On poorer soils in Brazil, however, *E. grandis* and *E. saligna* were found to be more efficient in using nutrients than *E. dunnii* (Silva H.D. *et al.*, 1983).

Limited studies of stand thinning and stand edges in Brazil (Graca 1987) show that flowering is more abundant with increased availability of light. In Australia, flowering occurs in March and capsules mature over winter. Observations from seed collectors suggest that there is a consistent shedding at the peduncle – pedicel joint, of the four outside capsules before they reach maturity thereby leaving three capsules in the umbellaster (C. Gardiner pers. comm.). Little is known about pollination in the species.

Oliveira (1988) notes that *Eucalyptus dunnii* produces a low quantity of seed in Brazilian plantations thus slowing down some planting programs. Similarly, it is generally a low and unreliable seeder in Australia (Oliveira 1988 and C. Gardiner pers. comm.). Because of its value in the development of overseas plantations, there has been a high demand for *E. dunnii* seed from Australia (valued at A$1300 kg in 1991, C. Gardiner pers. comm.). The following observations on seed production have been made by C. Gardiner of the CSIRO Australian Seed Tree Centre:

* A heavy crop of seed has been produced in only three of the last 25 years. Two of the three heavy seed crops were observed for the dry years of 1990 and 1991. Little seed was observed in 1992.

* *Eucalyptus dunnii* seems not to be an opportunistic seeder as seed is consistently shed over the summer months before the next flowering begins.

* Seed production is not uniform between populations. While one population may be bearing seed, another may not.

In Australia, the foliage of *E. dunnii* is prone to insect attack, particularly by members of the Psyllidae (lerps). Heavy infestations have been observed to cause death in trees (C. Gardiner pers. comm.) The relative attractiveness of *E. dunnii* to insect attack compared to *E. grandis* has led to it being planted as an insect lure on the edge of *E. grandis* plantations (A. Floyd pers. comm.).

Research on the resistance to termite (*Macrotermes natalensis*) attack (South African Institute for Commercial Forestry Research 1988) ranked *E. dunnii* as being more resistant than all other species of *Eucalyptus* tested. Little is known about its resistance to Australian termite species.

In contrast to its success in pulp production overseas (and use as veneer timber in Australia), Australian foresters and timber companies consider the saw-log timber derived from *E. dunnii* is low in quality, compared to species such as *E. saligna* (Sydney Blue Gum). It has a tendency to warp and shrink during the drying process (E. Chiswell pers. comm., M. Combe pers. comm.).

Methods

Herbarium records from the National Herbarium of NSW, data from the NSW National Parks and Wildlife Service rare plant database and the Forestry Commission's forest type maps formed the basis for identifying the main locations of *E. dunnii*. The term location used in this paper refers to distinct geographic areas such as a mountain range or a creek catchment. Eight of the 10 locations were sampled by means of quadrat-based sites. A total of 30 sites covering the major habitat types and disturbance histories across the geographical distribution of the species were sampled in April 1991.

At each site two quadrats of different sizes were recorded. As far as possible, quadrats were positioned in the centre of stands of *E. dunnii*. The diameter of the tree trunk at breast height (dbh) of all specimens of *E. dunnii* was measured within a 50 X 50 m quadrat. The dbh measurements were assigned to one of three dbh classes (0–0.5 m, 0.51–1.25 m, >1.26 m).

A 20 X 20 m quadrat was placed within the 50 X 50 m quadrat and its floristic composition recorded. Each vascular plant species was assigned a percentage cover rating, using a modified Braun-Blanquet (1932) scale. A structural classification of the vegetation at each site was described using Walker and Hopkins (1990). This included the recognition of different strata in the vegetation and the dominant species therein. Estimates of the time since the last fire or logging were also recorded. Data on altitude, slope, aspect and substrate/soil were recorded.

Abundance data from the sample sites within each location were averaged and extrapolated to give estimates of present population for each of the eight sampled and two unsampled geographical locations. The dbh data are similarly grouped, but the proportion of trees in each size class are given for each site. Some smaller stands of *E. dunnii* on private land, including narrow bands of trees extending down creeks into drier, non-basalt country, were not sampled, although estimates of numbers at some sites are provided. The extent of *E. dunnii* communities on various tenures of land were estimated using a dot matrix overlay on Forestry Commission vegetation type maps and field checked with the assistance of aerial photographs. Geographic locations, such as the Tooloom Range (which extends for over 40 km north to south), contain several populations of *E. dunnii*.

Because some small, remote or inaccessible populations may have been overlooked during the survey, data on the total extent and total population should be considered to be an under-estimate.

To generate site and floristic classifications, the data were subjected to pattern analysis using the PATN package (Belbin 1989). The data matrix included 201 species. This excluded species that only occurred once in the survey and had a cover rating of 1, which add little to the analysis of patterns. The Bray-Curtis association measure (Bray and Curtis 1957) was used to compare the sites according to similarities in their species composition. This measure of association was used in a 'unweighted paired group arithmetic averaging' (UPGMA) (Sneath and Sokal 1973, Belbin 1989) hierarchical clustering strategy and a dendrogram was generated. The clustering parameter (Beta) was set at -0.1. A list was produced which records presence or absence of species from the major groupings defined in the UPGMA cluster analysis.

Results

Distribution and abundance

In NSW there are approximately 82,000 individuals of *E. dunnii* covering approximately 795 hectares distributed over 10 locations (Table 1) from just north of Moleton in the south (Lat. 30°08'S), to the Queensland–NSW border in the north (Lat. 28°18'S) (Figures 3 and 4).

The major populations of *E. dunnii* occur in the upper Clarence River catchment on the McPherson Range (which forms the border between NSW and Queensland) and the north-south orientated, basalt dominated ranges (Acacia Plateau, Koreelah Range, Tooloom Range and Richmond Range) that radiate from it (Tables 1 and 2, Figure 3). These ranges are eroded features of the Focal Peak Volcano which erupted in the

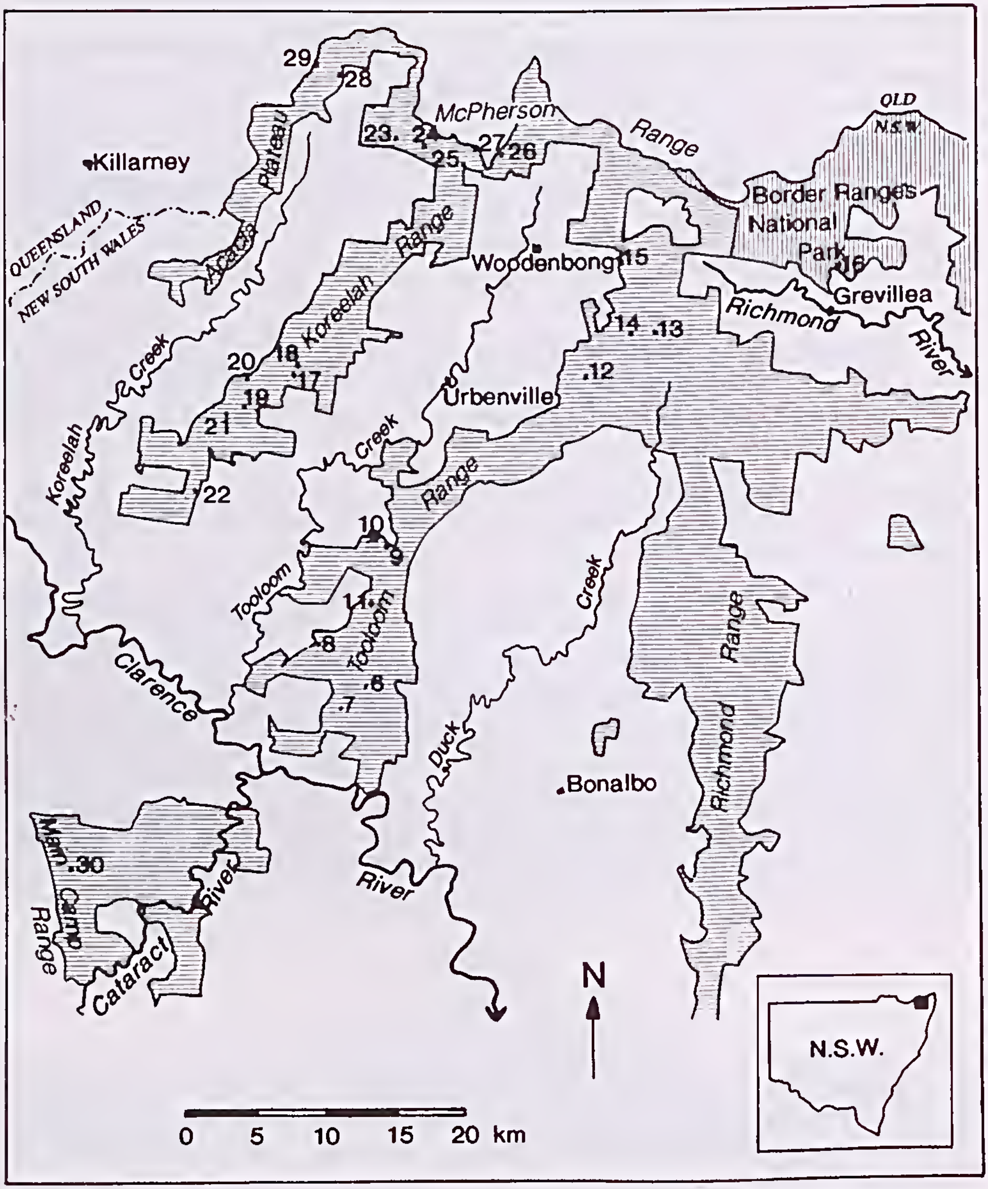

Figure 3. The major populations of *Eucalyptus dunnii* occur on the basalt capped ranges of far north-east NSW. The populations are restricted in size and extent and mainly occur in state forest which is hatched. Sample sites are numbered 6–30.

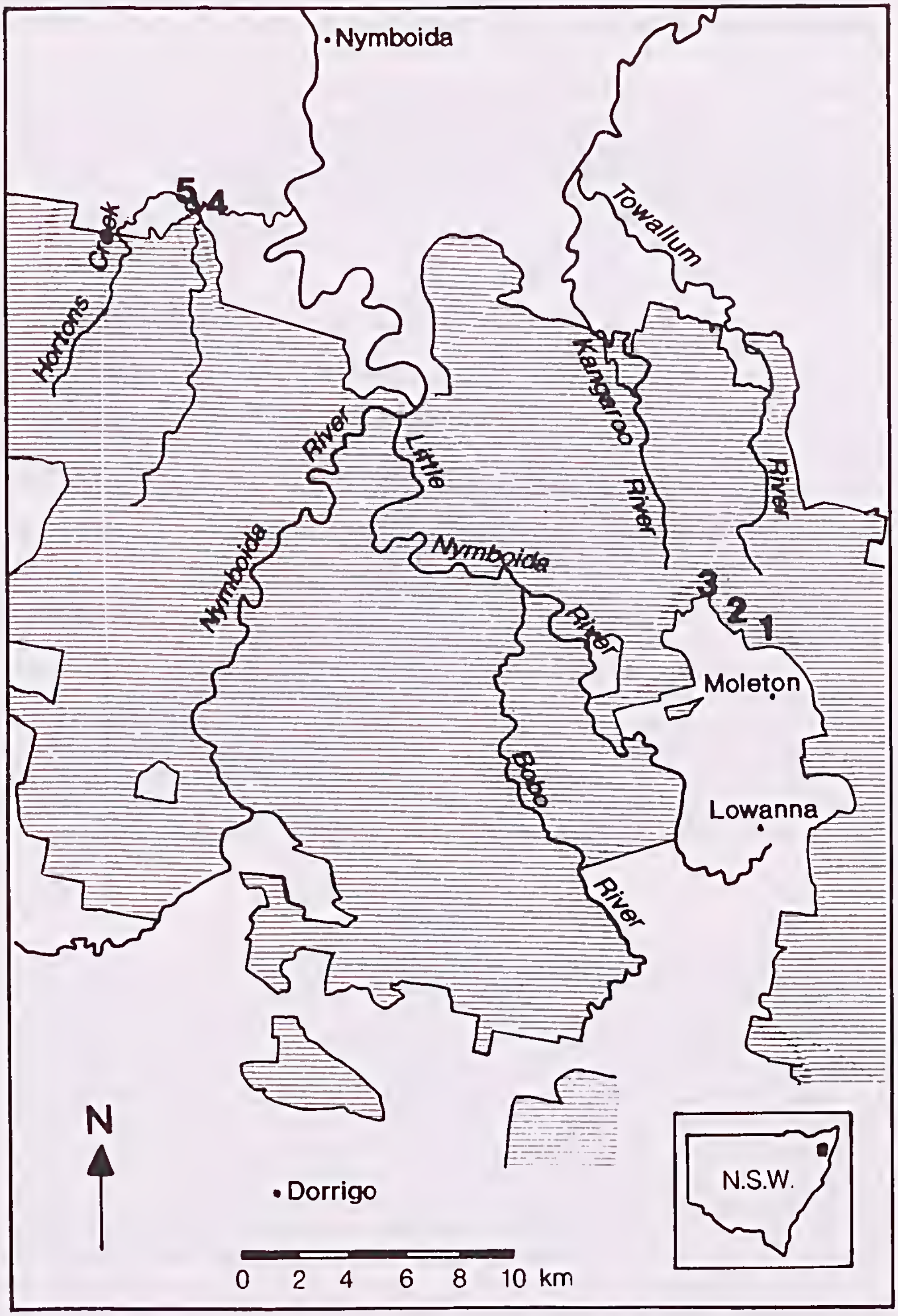

Figure 4. Occurrences of *Eucalyptus dunnii* in the Moleton–Hortons Creek areas inland from Coffs Harbour. Sites are numbered 1–5. Hatched area is state forest.

Tertiary period approximately 25 million years ago. This volcano produced numerous flows of basalt and rhyolite (Stevens 1977, Floyd 1979a, 1979b). Three small populations were recorded in the Richmond River catchment, the eastern-most of which was Terrace Creek, partly inside Border Ranges National Park.

Several populations occur 140 km south of the Focal Peak region (Figure 4). The southernmost locality for the species is at Mole Creek, 4 km north of Moleton which is situated on the coastal ranges 30 km north west of Coffs Harbour. Other populations occur in the adjoining state forests north of Mole Creek. An isolated population is present near the junction of Hortons and Clouds Creeks, 25 km north-west of Moleton and 10 km south of Nymboida. These southern stands of *E. dunnii* also grow on enriched loamy soils but these are derived from a different volcanic source than the rich soils in the Focal Peak region.

A small stand of *E. dunnii* in Gilgurry State Forest north east of Tenterfield represents a western outlier of the species. In common with southern occurrences it is growing on an enriched loamy red soil derived from a small area of residual basalt.

Areas of *E. dunnii* identified on Forestry Commission 1:25 000 scale forest type maps were generally confirmed by the survey. One notable exception is a 70 ha area below Acacia Plateau which was discovered to be *E. saligna*. This area is not accessible by road, which may have restricted ground truthing of the forest typing.

Several isolated populations of *E. dunnii* occur in Queensland near its border with NSW. One stand is on the north-western side of Lamington National Park at Duck Creek, mostly on the private land near O'Reilly's Guest House (W. McDonald pers. comm.). The species is also recorded from Main Range National Park (Briggs and Leigh 1988) in populations contiguous with or close to those of the MacPherson Range. A few hundred individual trees are known from Burnett Creek on the western side of Mount Barney. Clearing for pine plantation has limited the population of *E. dunnii* in Gamubal State Forest, north east of Killarny (P. Young pers. comm.). The most northern location of *E. dunnii*, and the largest stand in Queensland, is located at Spicers Gap on the Cunningham Gap Road approximately 25 km north of the NSW border. In total there would be approximately 300 ha of *E. dunnii* forest in Queensland (P. Young pers. comm.) but little data is available on population or size class structure.

Habitat

Our survey confirmed that *E. dunnii* grows on high nutrient soils. All sample sites were located either on basalt, or on colluvium or alluvium influenced by the presence of basalt upslope or upstream. Surface soils have a neutral pH falling between 6.5 and 7 (C. Gardiner pers. comm.). At its southernmost locations near Moleton, *E. dunnii* grows on red-brown loams derived from residuals of the Towallum Basalt (Dorrigo–Coffs Harbour 1:250 000 geology map). Basalt is also present upslope from its occurrence at Hortons Creek (Floyd 1977). At its northern locations in NSW, *E. dunnii* most often grows on chocolate soils (black earths) derived from basalt (Beckman and Thompson 1977, Floyd 1979a, 1979b). One exception to this is the population in the Peacock Creek valley on the western side of the Richmond Range. This relatively dry site is underlain by sedimentary rocks but there is some basalt enriched alluvium on the creek flats which is where most of the *E. dunnii* grows. The Queensland populations of *E. dunnii* are also confined to basalt and enriched alluvium (P. Young pers. comm.).

Table 1. Occurrence of *Eucalyptus dunnii* communities on various tenures

Location	**Tenure**	**Area (ha)**	**Number of trees**
Kangaroo Creek SF, Moleton	State forest	60	4,900
Clouds/Hortons Creek	Private	23#	3,600
	Crown land	9	2,600
Tooloom Range	State forest	90	9,500
	Private	5	530
Richmond Range	State forest	100	7,700
	Private	1	80
Koreelah Range	State forest	195	22,900
	Flora reserve	35	5,200
	Private	18	2,200
MacPherson Range	State forest	105	10,500
	Flora reserve	9	760
	National Park	5	260
	Private	5	490
Acacia Plateau	State forest	91	6,900
	Private	8	710
Gilgurry	State forest	8	690
Acacia Creek	Private	18	1,600*
Tooloom Creek	Private	5	710*
	Crown land	5	200*
Total (ha)	State forest^x	649	63,100
	Reserves	49	6,200
	Crown land	14	2,800
	Private	83	9,900
	Total	**795**	**82,000**
Total (%)	State forest^x	81.6	76.9
	Reserves	6.2	7.6
	Crown land	1.8	3.4
	Private	10.4	12.1

^{x} Excludes flora reserves * Estimate
Includes 10ha in the process of incorporation into a nature reserve

Note: Number of trees is extrapolated from quadrat data presented in Table 3.
Locations recently disturbed by logging may have the greatest number of trees per ha due to regeneration, but these trees are generally smaller in size than those growing in less recently disturbed locations.

Eucalyptus dunnii grows on a range of aspects but rarely occurs on north-western facing slopes (Table 2). It mainly grows between the altitudes of 400 m and 650 m. The lowest recorded elevation is Terrace Creek in the Border Ranges National Park (210 m) and highest at Mount Clunie Flora Reserve on the McPherson Range (790 m) (Table 2).

Table 2. Site attributes for *Eucalyptus dunnii* occurrences

Location	Site	Easting	Northing	Elev. (m)	Slope (°)	Aspect (°)
Kangaroo Creek SF, Moleton	1	4905	66658	430	10	40
	2	4893	66662	460	2	0
	3	4884	66674	490	0	0
Clouds/Hortons Creek	4	4693	66811	220	2	110
	5	4692	66813	240	6	140
Tooloom Range	6	4495	68283	590	3	20
	7	4476	68267	320	2	10
	8	4462	68317	650	10	232
	9	4508	68383	660	10	170
	10	4500	68388	570	4	162
	11	4501	68342	560	2	274
	12	4651	68496	600	15	356
Richmond Range	13	4669	68528	440	5	270
	14	4682	68531	550	3	232
	15	4683	68583	400	15	36
Koreelah Range	17	4447	68501	420	1	80
	18	4452	68510	430	2	262
	19	4413	68482	630	8	240
	20	4415	68503	760	6	296
	21	4399	68399	610	5	115
	22	4373	68412	540	8	110
MacPherson Range	16	4826	68573	210	5	214
	23	4523	68666	790	20	162
	24	4544	68660	610	10	198
	25	4568	68651	600	12	130
	6	4592	68658	680	35	94
	27	4580	68663	630	4	310
Acacia Plateau	28	4487	6871400	595	0	0
	29	4466	6872300	770	20	96
Gilgurry	30	4281	6816300	670	10	45

Note: AMG eastings and northings include full digit code accurate to 100 m

Table 3. Number and proportion in size classes of *Eucalyptus dunnii* in sites and locations

Location	**Site**	**No. of trees**	$\bar{x}$	**S.E.**	**Proportion of trees within DBH classes (metres)**		
					0–.5	**.51–1.25**	**1.26–2**
Kangaroo Creek SF, Moleton	1	28	20.3	3.2	.68	.25	.07
	2	16			.94	.06	0
	3	17			.59	.29	.12
Clouds/Hortons Creek	4	73	NC	NC	.93	.05	.02
	5	11			.54	.36	.10
Tooloom Range	6	36	26.4	5.2	.97	.03	0
	7	18			.67	.22	.11
	8	36			.94	.06	0
	9	48			.94	.04	.02
	10	18			.67	.22	.11
	11	4			.75	.25	0
	12	25			.96	.04	0
Richmond Range	13	30	19	5.1	1	0	0
	14	18			.94	.06	0
	15	9			.89	.11	0
Koreelah Range	17	31	30.5	7.5	.97	.03	0
	18	12			.92	0	.08
	19	27			.96	.04	0
	20	68			.88	.11	.01
	21	31			.90	.10	0
	22	14			.93	.07	0
MacPherson Range	16	13	22.7	5.3	.77	.15	.08
	23	21			1	0	0
	24	11			1	0	0
	25	33			.88	.12	0
	26	12			.83	.17	0
	27	46			.98	0	.02
Acacia Plateau	28	21	NC	NC	.81	.10	.09
	29	17			.88	.06	.06
Gilgurry	30	30	NC	NC	.74	.22	.04
Acacia Creek	NR						
Tooloom Creek	NR						

NR: not recorded - Acacia Creek and Tooloom Creek locations were not sampled
NC: not calculated
Site: 50 X 50 m quadrat
$\bar{x}$ (mean) and S.E. (standard error) are provided for locations where sites >2

Population structure

The dbh data (Table 3) reveal that, as of 1991, an overwhelming proportion of the population was composed of small trees. Eighty-six per cent of individuals were in the 0-0.5 m size class compared to 11% in the 0.51–1.25 class and 3% in the >1.25 class. At undisturbed sites with moist understorey species the data suggests that 'old growth' stands may have a ratio of large/medium to small trees in the order of two to three. In contrast most of the current populations occur in recently disturbed sites and contain about nine small trees to each large or medium sized tree.

Very few stands of 'old growth' *E. dunnii* forest were located during the survey. Only five sites contained >30% of trees in the medium to large categories (>0.51 m dbh). These were site 1 near Averies Creek on the border of Kangaroo River State Forest and Bagawa State Forest; site 3 adjacent to Black Mountain Road in Kangaroo River State Forest; site 5 at Hortons Creek; and sites 7 and 10 in Yabbra State Forest on the Tooloom Range.

Regeneration of young trees was observed at all sites, but was most vigorous at sites where there had been recent disturbance (Figure 5), mainly due to logging or clearing over the last 40 years. Under natural conditions mass regeneration would probably

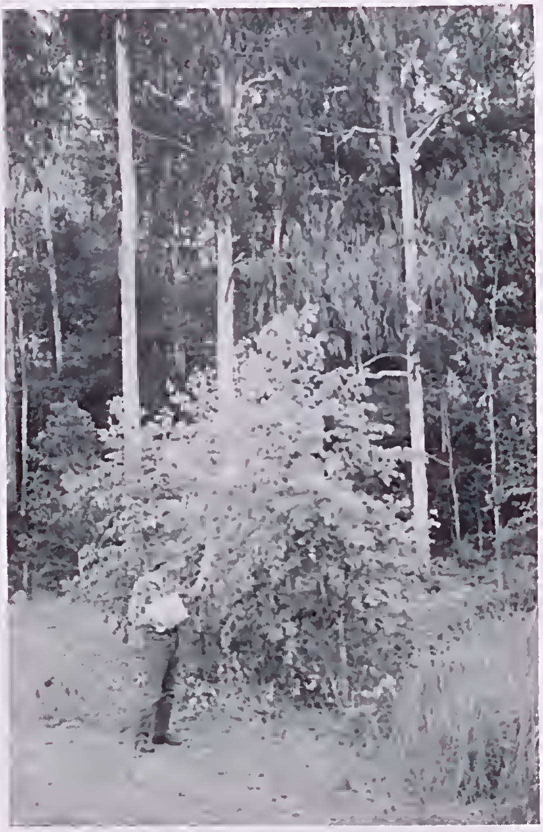

Figure 5. The quick-growing *Eucalyptus dunnii* regenerates well after disturbance although frequent fire may cause a long-term population decline.

occur after hot wildfires or cyclones have disturbed the forest. In this sense *E. dunnii* may behave in a similar fashion as other fire sensitive eucalypts, such as *E. regnans* which forms even aged stands after fire, regenerates on an ashbed and self-thins over time (Ashton 1976). At most locations the natural fire frequency would be expected to be low, since *E. dunnii* grows on moist sites dominated by largely non-flammable species. Large trees (Figure 6) would be common in areas that have not been severely burnt or affected by cyclones for over 150 years (authors' estimate).

Associated plant species

Throughout its range *E. dunnii* occupies an ecotonal zone between drier eucalypt forest and rainforest. The understorey is usually dominated by colonising rainforest species, with the families Myrtaceae, Euphorbiaceae, Lauraceae and Meliaceae prominent.

Eucalyptus saligna, E. grandis, E. microcorys and *Lophostemon confertus* commonly co-dominate the forest canopy with *E. dunnii*. Several strata are generally present below the canopy of these tall eucalypts. Small to medium-sized trees up to 20 m high make up the next tallest stratum. This is mostly composed of regenerating

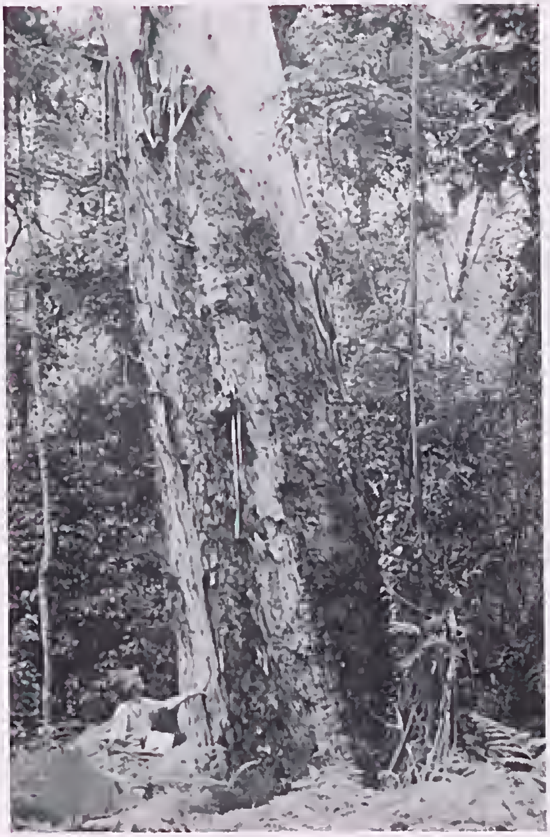

Figure 6. Due to logging over recent decades, few mature, large specimens of *Eucalyptus dunnii* remain. This large specimen was located adjacent to Wallaby Creek.

eucalypts but in the vicinity of mature rainforest *Araucaria cunninghamia, Diploglottis australis* and *Toona australis* are commonly present. The next layer is most often composed of rainforest trees, tall shrubs and vines including *Neolitsea australiensis, Neolitsea dealbata, Alectryon subcinereus, Cryptocarya rigida, Cryptocarya glaucescens, Diospyros australis, Polyscias elegans, Acacia maidenii, Rhodamnia rubescens, Acmena smithii, Croton verrauxii, Cordyline petiolaris, Cordyline stricta, Cissus hypoglauca* and *Cissus antarctica.* A frequently occurring and major weed species is *Lantana camara* which dominates the understorey at sites that have been substantially disturbed by logging, fire or clearing. *Senna floribunda* and *Ageratina adenophora* are other commonly recorded, introduced plants.

On moist sites, estimated by the authors not to have been burnt for more than 30 years, ferns, vines and herbs dominate the forest floor. Common species include the ferns *Adiantum formosum, Lastreopsis spp., Hypolepis glanduligera, Doodia aspera, Dennstaedtia davallioides;* vines such as *Derris involuta, Palmeria scandens* and *Rubus hillii* and forbs such as *Pollia cristata, Alpinia caerulea* and *Alocasia brisbanensis.*

A different array of ground species dominate at drier sites which have been regularly burnt (every 10 years or so) or which have been recently logged. These include *Pteridium esculentum, Imperata cylindrica* and *Poa labillarderi.* The herbaceous weed species, *Ageratina adenophora* (crofton weed), was present at heavily disturbed sites.

A total of 239 species of vascular plants were recorded as occurring with *E. dunnii* (Table 4) of which 12 species (5%) were introduced weeds.

Plant community variation

There is a remarkable similarity of floristic composition throughout the range of *E. dunnii* forests in NSW. Observations suggest floristic differences can be explained by disturbance history, particularly recent fire or logging, rather than changes in physiography. This is supported by the UPGMA cluster analysis which grouped the sites into three main floristic groups (groups selected at the 0.8 level of dissimilarity, Figure 7). Group 1 contains sites rich in species, the great majority of which are either pioneer or latter stage rainforest plants. Group 2 contains a combination of rainforest pioneer species and dry sclerophyll species recovering after disturbance within the last two decades. Group 3 contains the two most heavily disturbed sites (11 and 29) both of which had been recently heavily logged and burnt and were species poor.

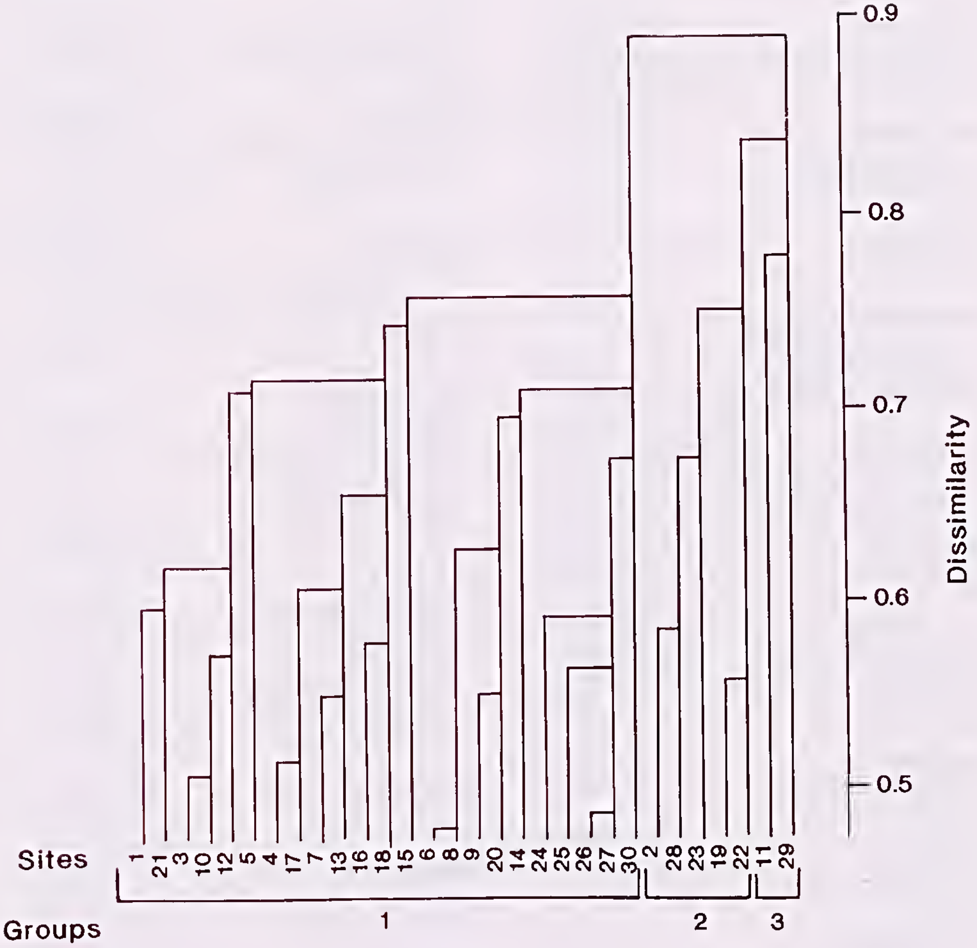

Figure 7. UPGMA generated dendrogram showing the floristic relationships between sites atwhich *Eucalyptus dunnii* occurs. Brackets show the floristic groupings at the 0.8 level of dissimilarity. This grouping appears to reflect disturbance history.

Table 4. Species occurring in *Eucalyptus dunnii* communities
(# after species denotes exotic)

UPGMA Group	1	2	3
PTERIDOPHYTES			
Adiantaceae			
Adiantum aethiopicum	*	*	
Adiantum formosum	*	*	
Adiantum hispidulum	*		
Pellaea falcata var. falcata		*	
Pellaea paradoxa	*	*	
Aspidiaceae			
Lastreopsis acuminata	*		
Lastreopsis decomposita	*		
Lastreopsis microsora	*		
Lastreopsis munita	*		
Asplenium australasicum	*	*	
Blechnaceae			
Blechnum cartilagineum	*		
Doodia aspera	*	*	
Cyatheaceae			
Calochlaena dubia	*	*	
Cyathea leichhardtiana	*		
Davalliaceae			
Davallia pyxidata			
Dennstaedtiaceae			
Dennstaedtia davallioides	*		
Hypolepis glandulifera	*		
Pteridium esculentum	*	*	
Polypodiaceae			
Platycerium bifurcatum	*		
Platycerium superbum	*	*	
Pteridaceae			
Pteris tremula	*		
GYMNOSPERMS			
Araucariaceae			
Araucaria cunninghamii	*		
ANGIOSPERMS			
Agavaceae			
Cordyline petiolaris	*	*	
Cordyline stricta	*		
Alangiaceae			
Alangium villosum	*		
Amaranthaceae			
Nyssanthes diffusa	*	*	
Anacardiaceae			
Euroschinus falcata	*		
Annonaceae			
Rauwenhoffia leichhardtii	*		
Apiaceae			
Hydrocotyle pedicellosa	*		
Apocynaceae			
Alyxia ruscifolia	*	*	
Melodinus australis	*		
Parsonsia fulva		*	
Parsonsia straminea	*		
Parsonsia velutina	*		
Araceae			
Alocasia brisbanensis	*		
Gymnostachys anceps	*	*	
Araliaceae			
Cephalaralia cephalobotrys	*		
Polyscias elegans	*	*	*
Polyscias murrayi	*	*	
Arecaceae			
Archontophoenix cunninghamiana	*		
Linospadix monostachya	*		
Livistona australis	*		
Asclepiadaceae			
Araujia hortorum#			*
Gomphocarpus fruticosus#		*	
Marsdenia flavescens	*		
Marsdenia suberosa	*		
Marsdenia velutina	*	*	
Asteraceae			
Ageratina adenophora#	*	*	
Bidens pilosa#	*	*	*
Conyza albida#			*
Ozothamnus rufescens	*		
Helichrysum rutidolepis		*	
Tagetes minuta#	*		
Bignoniaceae			
Pandorea pandorana	*	*	
Boraginaceae			
Austrocynoglossum latifolium	*		
Ehretia acuminata	*	*	
Capparaceae			
Capparis sarmentosa	*		

UPGMA Group	**1**	**2**	**3**
Casuarinaceae			
Allocasuarina torulosa		*	
Casuarina cunninghamiana	*		
Celastraceae			
Cassine australis	*	*	
Celastrus subspicatus	*	*	
Denhamia celastroides	*		
Maytenus bilocularis	*		
Maytenus silvestris	*	*	
Commelinaceae			
Aneilema acuminatum	*		
Commelina cyanea	*		
Pollia crispata	*	*	*
Convolvulaceae			
Dichondra repens		*	
Cucurbitaceae			
Zehneria cunninghamii	*		
Cunoniaceae			
Aphanopetalum resinosum	*		
Caldcluvia paniculosa	*		
Cyperaceae			
Carex appressa	*	*	
Gahnia melanocarpa	*	*	
Lepidosperma laterale		*	
Dilleniaceae			
Hibbertia scandens	*	*	
Dioscoreaceae			
Dioscorea transversa	*		
Ebenaceae			
Diospyros australis	*	*	
Diospyros pentamera	*	*	
Elaeocarpaceae			
Elaeocarpus obovatus	*	*	
Epacridaceae			
Acrotriche latifolia	*		
Trochocarpa laurina	*		
Euphorbiaceae			
Baloghia inophylla	*		
Breynia oblongifolia	*	*	
Bridelia exaltata	*		
Claoxylon australe	*	*	
Cleistanthus cunninghamii	*		
Coelebogyne ilicifolia	*		
Croton verreauxii	*	*	*
Drypetes australasica	*		
Glochidion perakense	*		
Mallotus philippensis	*	*	
Omalanthus populifolius	*		
Eupomatiaceae			
Eupomatia laurina	*	*	
Fabaceae			
Faboideae			
Austrosteenisia glabristyla	*		
Derris involuta	*	*	
Desmodium nemorosum	*		
Glycine clandestina		*	
Goodia lotifolia	*		
Indigofera australis		*	
Kennedia rubicunda	*	*	
Swainsona galegifolia	*		
Caesalpinioideae			
*Senna floribunda**	*	*	
Mimosoideae			
Acacia filicifolia	*	*	*
Acacia irrorata ssp. irrorata	*	*	
Acacia maidenii	*	*	
Acacia melanoxylon	*	*	*
Flacourtiaceae			
Scolopia braunii	*		
Icacinaceae			
Pennantia cunninghamii	*		
Lamiaceae			
Plectranthus parviflorus	*	*	
Lauraceae			
Beilschmiedia obtusifolia	*		
Cinnamomum oliveri	*		
Cryptocarya erythroxylon	*		
Cryptocarya glaucescens	*		*
Cryptocarya microneura	*	*	
Cryptocarya obovata	*		
Cryptocarya rigida	*	*	
Cryptocarya triplinervis var. pubens	*		
Endiandra muelleri	*		
Endiandra sieberi	*		
Neolitsea australiensis	*	*	
Neolitsea dealbata	*		
Liliaceae			
Dianella caerulea	*		
Malvaceae			
Abutilon grandifolium	*		
Hibiscus heterophyllus	*	*	
Meliaceae			
Anthocarpa nitudula	*		
Dysoxylum fraseranum	*		*
Dysoxylum rufum	*		
Melia azedarach	*	*	
Synoum glandulosum	*	*	
Toona australis	*		

Table 4 (cont'd)

UPGMA Group	**1**	**2**	**3**
Menispermaceae			
Legnephora moorei	*		
Sarcopetalum harveyanum	*	*	
Stephania japonica	*	*	*
Monimiaceae			
Daphnandra micrantha	*		*
Doryphora sassafras	*		
Hedycarya angustifolia	*	*	
Palmeria scandens	*		
Moraceae			
Ficus coronata	*	*	
Ficus watkinsiana	*		
Maclura cochinchinensis	*	*	*
Malaisia scandens	*	*	
Myrsinaceae			
Embelia australiana	*		
Rapanea howittiana	*		
Rapanea variabilis	*	*	
Myrtaceae			
Acmena smithii	*		*
Angophora subvelutina	*	*	
Austromyrtus bidwillii	*		
Callistemon salignus	*	*	
Eucalyptus acmenioides	*		
Eucalyptus dunnii	*	*	*
Eucalyptus grandis	*		
Eucalyptus maculata	*		
Eucalyptus microcorys	*	*	
Eucalyptus propinqua	*	*	
Eucalyptus saligna	*	*	*
Eucalyptus siderophloia	*		
Eucalyptus tereticornis		*	*
Lophostemon confertus	*	*	*
Melaleuca bracteata	*		
Rhodamnia rubescens	*	*	
Rhodomyrtus psidioides	*		
Syncarpia glomulifera		*	
Syzygium australe	*		
Syzygium oleosum	*		
Tristaniopsis laurina	*		
Oleaceae			
Notelaea venosa	*	*	
Orchidaceae			
Calanthe triplicata	*		
Passifloraceae			
*Passiflora edulis**	*	*	
*Passiflora foetida**	*		
*Passiflora subpeltata**	*		
Philesiaceae			
Geitonoplesium cymosum	*	*	*

UPGMA Group	**1**	**2**	**3**
Pittosporaceae			
Billardiera scandens		*	
Citriobatus pauciflorus	*	*	*
Hymenosporum flavum	*		
Pittosporum revolutum	*	*	
Pittosporum rhombifolium	*		
Pittosporum undulatum	*	*	
Poaceae			
Imperata cylindrica	*	*	*
Oplismenus imbecillis	*	*	
Poa labillardieri		*	
Themeda australis		*	
Proteaceae			
Grevillea robusta	*		
Persoonia attenuata		*	
Ranunculaceae			
Clematis aristata	*		*
Clematis glycinoides	*		
Rhamnaceae			
Alphitonia excelsa	*		
Rosaceae			
Rubus hillii	*	*	
Rubus rosifolius	*	*	
Rubiaceae			
Canthium buxifolium		*	
Hodgkinsonia ovatiflora	*		
Morinda jasminoides	*		
Psychotria daphnoides	*	*	
Psychotria loniceroides	*	*	
Rutaceae			
Acronychia oblongifolia	*	*	
Euodia micrococca	*	*	
Geijera salicifolia	*	*	
Sarcomelicope simplicifolia	*		
Zanthoxylum brachyacanthum	*		
Santalaceae			
Santalum obtusifolium		*	
Sapindaceae			
Alectryon subcinereus	*	*	
Arytera divaricata	*		
Cupaniopsis parvifolia	*	*	
Diploglottis australis	*		
Elattostachys nervosa	*		
Guioa semiglauca	*	*	
Sarcopteryx stipitata	*		
Sapotaceae			
Planchonella australis	*		

UPGMA Group	**1**	**2**	**3**
Smilacaceae			
Ripogonum album	*		
Ripogonum discolor	*		
Ripogonum elseyanum	*		
Smilax australis	*	*	*
Solanaceae			
Duboisia myoporoides	*		
Solanum aviculare	*		
Solanum campanulatum	*		
Solanum cinereum	*		
*Solanum mauritianum**	*		*
Solanum stelligerum	*	*	
Sterculiaceae			
Heritiera antinophylla	*		
Symplocaceae			
Symplocos thwaitesii	*		
Thymelaeaceae			
Phaleria chermsideana	*		
Pimelea ligustrina			*
Pimelea pauciflora		*	
Wikstroemia indica	*	*	
Ulmaceae			
Aphananthe philippinensis	*		
Trema aspera	*	*	

UPGMA Group	**1**	**2**	**3**
Urticaceae			
Dendrocnide excelsa	*	*	*
Dendrocnide photinophylla	*		
Elatostema reticulatum	*		
Urtica incisa	*		
Verbenaceae			
Clerodendrum tomentosum	*	*	
*Lantana camara**	*		
Vitaceae			
Cayratia clematidea	*		
Cissus antarctica	*	*	*
Cissus hypoglauca	*	*	
Cissus sterculiifolia	*		
Tetrastigma nitens	*	*	
Winteraceae			
Tasmannia insipida	*		
Xanthorrhoeaceae			
Lomandra longifolia	*	*	
Zingiberaceae			
Alpinia caerulea	*		

Conservation

Of the estimated 795 ha of *E. dunnii* forest community in NSW, 87% (693 ha) occurs in state forest. Of this 6% (44 ha) is protected in flora reserves managed by the Forestry Commission. The only sample represented in reserves managed by the NSW National Parks and Wildlife Service is 5 ha in Border Ranges National Park, the understorey of which is engulfed by *Lantana*. Therefore, just over 6% of the area of *E. dunnii* is located in conservation reserves. About 10% (83 ha) is estimated to remain on private land and a small area is located on Crown land (Table 1).

It is estimated that 6200 individuals of *E. dunnii* are conserved in reserves (Table 1). The largest protected population is in Tooloom Scrub Flora Reserve in Beaury State Forest near Urbenville. Another population is reserved in Mount Clunie Flora Reserve in Koreelah State Forest north of Urbenville. The two major reserved populations in flora reserves managed by the Forestry Commission have been partially logged in the past (Forestry Commission of NSW 1989b). They contain large numbers of post logging saplings.

The recently gazetted Hortons Creek Nature Reserve conserves 10 ha of *Eucalyptus dunnii* containing approximately 540 trees. Small stands are protected in two conservation reserves in Queensland (Main Range and Lamington National Parks).

Discussion

The fact that *E. dunnii* survives in disjunct populations on high nutrient soil raises the question of its origin and history. Silva's (1983) findings that *E. grandis* and *E. saligna* grow better than *E. dunnii* on low fertility soils suggest that *E. dunnii* may be more dependent than these other eucalypts on the presence of rich soil such as that derived from basalt. Consequently, it may have been more common in the geological past but has been restricted by the erosion of much of the original Tertiary basalt, thus reducing the size of its potential habitat. Wallaby Knob near Wallaby Creek on the southern end of the Koreelah Range is one example of residual basalt in a valley now dominated by Jurassic sedimentary rocks (Floyd 1979c). Studies of genetic variation between isolated populations may yield information on the relative levels of differentiation and therefore estimates of the time since the population was more continuous. Alternatively, the disparate populations could have arisen through seed dispersal, although the mechanisms for this are not known.

The survival of *E. dunnii* seedlings in the presence of rainforest species indicates it has a capacity to grow rapidly after disturbance. Seedlings presumably need to gain height quickly to reach available light before they are smothered by broad-leafed rainforest vines and shrubs. It would seem that intermittent disturbance is important for the survival of stands of *E. dunnii*, otherwise it would eventually senesce and be replaced by rainforest, although we did observe seedlings germinating in localised openings (10 m diameter) of the rainforest canopy. There is little documentation on the frequency of disturbance (fire, cyclone) in pre-European times. In protected situations it may have been in the order of hundreds of years based on the size of several species of trees (*E. saligna*, *E. dunnii*, *E. grandis* and *Lophostemon confertus*) in undisturbed sites. While *E. dunnii* appears not to be opportunistic in timing its seed shedding, the fact that this happens during summer coincides with the wildfire and cyclone season. This may be an advantageous adaption to ensure successful recruitment after disturbance.

Threats

Since European settlement the main impacts on the population of *E. dunnii* have been due to clearing of river flats and foothills for grazing stock and logging of remaining forests. We do not have accurate figures on the species' original distribution but it would seem that a number of populations were cleared on alluvial flats at lower altitudes. This supposition is supported by the survival of old trees in the Urbenville Showground, along Tooloom Creek near Woodenbong and along Acacia Creek.

The size class data suggests that most of the populations of *E. dunnii* have been heavily logged over the last forty years. Few old growth stands remain and it appears that there has been a major shift towards smaller trees of younger age, but possibly a larger population.

Logging on a long rotation (say once in 150 years) is unlikely to threaten the species but increased fire frequency associated with post-logging management of the forest or repeated logging on short rotations may do so. If populations are burnt too often (at intervals less than 20 years) young trees, susceptible to even cool fires, may be killed before they reach seed-bearing age. This could lead to a fall in recruitment. Frequent fires also discriminate against fire sensitive rainforest understorey shrubs and trees.

Anecdotal evidence from seed collectors (C. Gardiner pers. comm.) suggests that large, old trees yield more seed than young ones. This may be related, in part, to the fact that old, tall trees are exposed to maximum light and there is evidence that increased light leads to greater seed production (Graca 1987). Therefore, seed production (and regenerative capacity) could benefit from the protection of remaining old trees in each population. It could also benefit from more medium-sized trees being left to attain full maturity.

Other threats include seed collection, insect attack and weed infestation. Some old trees have been severely pruned by seed collectors. The long-term effects of this activity have not been researched. *Lantana camara* is a major weed in some locations and may inhibit seedling establishment. Its vigour tends to decrease with increased shade that results from regrowth of trees in the middle and upper strata of the vegetation.

Adequacy of conservation

The present population statistics provide a somewhat inflated impression of the species abundance because of the degree of regeneration after recent logging of most stands. It is likely the population will decrease over time due to natural thinning in the stands.

It is estimated that between 5% and 10% of the 795 ha of *E. dunnii* forest remains unlogged, containing a relative high proportion of large, mature trees (derived from Tables 1 and 3). While the species is reasonably well conserved in the northern part of its range, there is very little overall representation of mature forest in these reserves. In the absence of repeated logging or burning this situation could improve over the next century.

Eucalyptus dunnii is not protected at its western-most occurrence in Gilgurry State Forest near Tenterfield. This small but geographically distinct population was heavily logged in 1990. Prior to logging, this stand was one of the last old growth *E. dunnii* forests remaining in NSW. Because *E. dunnii* is regenerating at the site, along with the presence of a good patch of sub-tropical rainforest, it is suggested that the Gilgurry site should be protected in a flora reserve.

The unlogged stand of *E. dunnii* at site 3 adjoining the Black Mountain Road at the southern end of its distribution warrants flora reserve status not only for *E. dunnii* but also for the unusual ridgetop presence of *Toona australis* (Red Cedar). To the east the existing Twelve Sixty Flora Reserve should be extended to protect the *E. dunnii* population near Averys Creek (site 1).

Only part of the *E. dunnii* stand at Hortons Creek is conserved in the Hortons Creek Nature Reserve. Most of the population is downslope and outside the reserve on land adjacent to Cloud's Creek. This area should be added to the nature reserve.

Additional areas of *E. dunnii* could also be protected in Yabbra State Forest which contains significant populations of the species. Also, further populations may be able to be conserved in Queensland where the species is apparently rarer than in NSW.

Based on its population and the likely impact of existing threats, *E. dunnii* is in no immediate danger of extinction. Due to its restricted distribution retention of the 3RCa status on the national rare or threatened list (Briggs and Leigh 1988) appears to be warranted.

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Prediction of the habitat for *Tetratheca juncea* in the Munmorah area, near Wyong, New South Wales

R.J. Payne

Abstract

Payne, R.J. (c/- Andrews Neil, 207 Albany Street North, Gosford, NSW Australia, 2250) 1993. Prediction of the habitat for Tetratheca juncea *in the Munmorah area, near Wyong, New South Wales.* Cunninghamia *3(1): 147–154. Tetratheca juncea* (Tremandraceae) is a rare plant of the coastal area between Wyong and Bulahdelah. A large population of the species at Munmorah is being reduced because its habitat is being destroyed by infrastructural development. Site conditions have been identified that may be used to locate other populations occurring further north and west of the current survey.

Introduction

Tetratheca juncea Sm. (Tremandraceae) is a species difficult to locate amongst natural vegetation. Its morphological features are such that it is not easily distinguished amongst other shrubs, herbs, grasses and graminoids in most seasons, but is conspicuous when in flower. Although collections have been recorded from the Sydney suburban area, it is now believed to be extinct there (Harden, 1992). Other occurrences are from the Wyong–Bulahdelah area north of Sydney (collections held in the National Herbarium of New South Wales and records of the New South Wales National Parks and Wildlife Service). It is included on the rare or threatened Australian plants list of Briggs and Leigh (1988) with a coding of 3VCi indicating that it is a vulnerable species and is inadequately conserved.

Previous collections provide scant information on the habitat of *Tetratheca juncea*. Residential development around Sydney has eliminated its habitat but a large population has recently been found in the Munmorah area, near Wyong, north of Sydney. The population at Munmorah lies alongside the Pacific Highway and occurs west as far as Point Wolstoncroft on the Triassic Clifton Sub-group geological formation (Uren, 1977). This paper provides details of the habitat of *Tetratheca juncea* and the future conservation needs of the population.

Locations

Tetratheca juncea has been recorded from localities between Sydney and Bulahdelah (Fig. 1). Collections from the Sydney area (e.g., Carlton, Kogarah, Bexley and Undercliff) are early records and the species is now believed to be extinct in those areas (Harden, 1992). Although no habitat details are given, localities suggest the species grew in areas of Hawkesbury Sandstone.

Collections from the Wyong to Bulahdelah area (Fig. 1) are poorly documented in herbarium records. They indicate that the species grows in poor sandy soils around Lake Macquarie but at Bulahdelah grows on a wider range of soils from clays to limestones. At Redhead it has been reported from aeolian sands.

Few of the past records give details of associated vegetation. At Swansea it has been reported in *Angophora costata–Eucalyptus haemastoma* forest whilst at Bulahdelah from woodland of *A. costata–Allocasuarina littoralis*. On the aeolian sand dunes at Redhead it occurs in *Banksia aemula* heathland.

In the Lake Macquarie area Bartrim and Martin (1986), Kidd (1991) and Winning (1992) have more recently documented specific sites for *Tetratheca juncea* and have given details of vegetation associated with the species. Both Bartrim and Martin (1986) and Winning (1992) describe it as occurring in woodland/forest of *Eucalyptus haemastoma, Eucalyptus gummifera* and *Angophora costata* although on one occasion it was recorded in forest of *E. maculata–E. paniculata* at Green Point. All of the sites reported occur in relative close proximity to Lake Macquarie with some outlying populations near Mt Sugarloaf to the north west.

Populations in the Munmorah area

Populations of *Tetratheca juncea* were recorded during field investigations in June 1991 in the Munmorah area. A corridor, approximately 5 kilometres long, through natural vegetation on hilltops and valleys between Munmorah and the Wallarah Colliery was examined. Surrounding lands covering a total area of 12 square kilometres including the Munmorah State Recreation Area and sites at Point Wolstoncroft were also examined, specifically on hilltops but not valleys. At least 14 sites revealed populations of *Tetratheca juncea*, although only eight sites are detailed here (Table 1). Both populations and isolated plants were recorded. A population was designated where more than 20 plant clumps could be recorded along a ridge length of 100 metres. A small population was considered to contain between 20 and 50 plant clumps but a large population was considered to contain more than 50 plant clumps.

At Munmorah *Tetratheca juncea* occurs only in low forest/woodland of the *Angophora costata* complex. Benson (1986) includes *Eucalyptus gummifera, E. capitellata* and *Allocasuarina littoralis* as the dominants in the association and classifies the community as 9(g) for the Gosford–Lake Macquarie map sheet. This aptly describes the association at Munmorah except that *Eucalyptus haemastoma* occasionally dominates also. The structure is generally a low open-forest with a low cover of herbs, shrubs, monocotyledons and grasses. Associated species in the understorey are variable but dominants include *Macrozamia communis, Acacia myrtifolia, Lomandra obliqua, Dodonaea triquetra, Pimelea linifolia, Pultenaea villosa* and *Lambertia formosa. Themeda australis* (Kangaroo grass) is always present as the dominating grass, either as a dense or sparse cover. Other grasses such as *Entolasia stricta* can sometimes be present but only as occasional plants.

Populations of *Tetratheca juncea* at Munmorah appear to be confined to narrow, long, smooth hilltops, although the habitat of one collection at Charmhaven nearby, (collection in National Herbarium of New South Wales) is described as 'clay soil alongside creek'. Where it is found on hilltops the population does not extend very far over side slopes and it could not be found alongside drainage lines in the gullies. The Munmorah population appears to be restricted to this topographical feature and appears to be made up of scattered individuals and small populations commonly occurring over a wide area.

Winning (1992) reports that *Tetratheca juncea* occurs in generally the same vegetation type for the larger populations in the Lake Macquarie area but a range of habitats were recorded. Small populations of plants were found to be present in heath vegetation on sands, in shrublands on sandflats, in gullies and in Spotted Gum–Ironbark forest. Kidd (1991) also reports the same vegetation type but in one location, Catherine

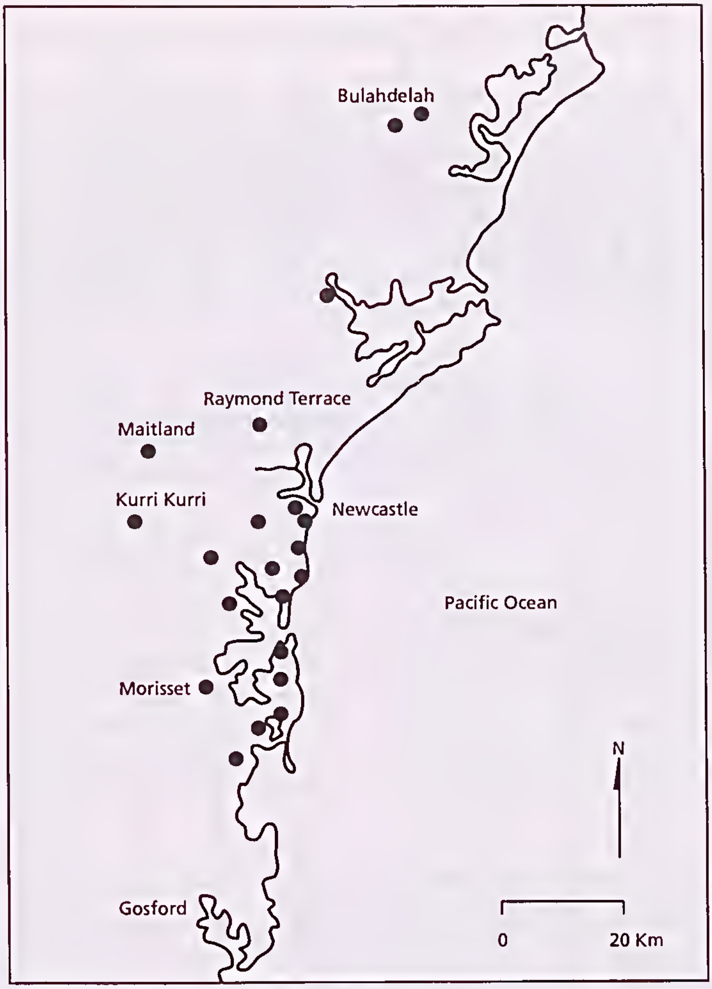

Figure 1. Reported locations of *Tetratheca juncea* from Lake Macquarie–Newcastle–Bulahdelah district.

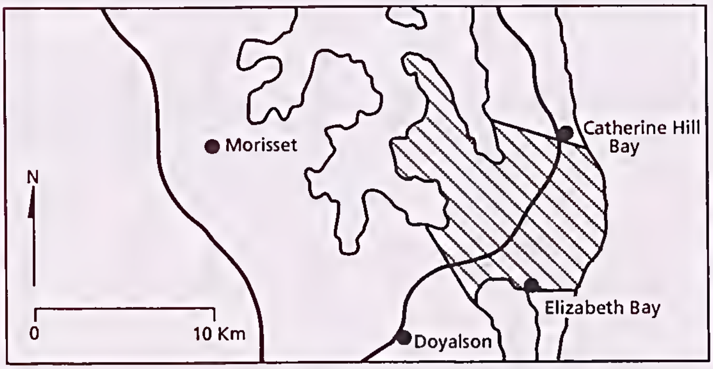

Figure 2. Area at Munmorah showing where *Tetratheca juncea* occurs (shaded).

Table 1 Site attributes for *Tetratheca juncea* at Munmorah. Site numbers refer to grid references on the Catherine Hill Bay 1:25 000 map sheet

Site	Topography	Soil	Vegetation	Distance from the sea	Abundance	Remarks
690275	Plateau	Shallow skeletal sand	*Angophora costata* complex (Forest)	3km	Isolated plants	Dense cover of *Themeda australis* and other shrubs
700275	Plateau	Shallow skeletal sand	*Angophora costata* complex (Low Woodland)	2km	Large population	Sparse ground cover due to wildfire 1990
705281	Plateau	Shallow skeletal sand	*Angophora costata* complex (Forest)	1.5km	Large population	Dense cover of *Themeda australis* and other shrubs
703268	Plateau	Shallow skeletal sand	*Angophora costata* complex (Low stunted Forest)	1km	Large population	Dense cover of *Themeda* other *australis* and other shrubs
701287	Plateau	Shallow skeletal sand	*Angophora costata* complex (Forest with some clearing)	2km	Small population	Sparse cover of *Themeda australis* and other shrubs – disturbed ground
703293	Plateau	Shallow skeletal sand	*Angophora costata* complex (Forest)	2km	Isolated plants	Dense cover of *Themeda australis* and other shrubs
702292	Plateau	Shallow skeletal sand	*Angophora costata* complex (Trees cleared)	2km	Large population	Disturbed ground. Some cover of *Themeda australis* and other shrubs
709299	Plateau	Shallow skeletal sand	*Angophora costata* complex (Forest)	2km	Isolated plants	Dense cover of *Themeda australis* and other shrubs

Hill Bay, the species was present in *Eucalyptus botryoides, Angophora* spp.–*Allocasuarina torulosa* forest.

The geology at Munmorah is the Clifton-subgroup of the Narrabeen Group (Uren, 1977). Exposed surfaces through roadside cuttings indicate a shallow sandy soil profile underlain by yellow sedimentary sandstone strata with conglomeritic and gravelly intrusions. Soil derived from this strata is a coarse yellow skeletal sand with little clay material present. Further north in the Lake Macquarie area the main populations tend to occur in clayey soils derived from conglomerates of the same geological formation. Specifically the populations were found to be present on ridges or upper slopes and generally favoured a southerly or easterly aspect (Winning, 1992).

Other soils on hilltops in the Munmorah locality are deeper grey podsolised sands which are also occupied by the *Angophora costata* complex but with a forest structure instead. Moist organic sandy soils and dry podsolised sands are also present where sedgelands of *Ptilanthelium duestum, Leptocarpus tenax* and *Lepyrodia scariosa* and heathlands of *Banksia oblongifolia, Hakea bakerana* and *Philotheca salsolifolia* occur. *Tetratheca juncea* does not appear to occur in the latter two habitats. On a broader scale the vegetation between the various populations where the species is now known to occur has not yet been investigated in different localities.

Tetratheca juncea is described as a coastal species (Harden, 1992) but appears to require some degree of shelter. The population at Munmorah does not occur adjacent to the sea and always lies behind the wind-sheared vegetation zone, although at Redhead it occurs in low heath directly exposed to onshore winds (Winning, pers.comm.). Elsewhere the species occurs inland as far as Maitland and Kurri Kurri (Fig. 1). Rainfall ranges from 1160 mm annually at Wyong to 926 mm at Newcastle (Bridgeman, 1984). For the Sydney sites it is about 1100 mm annually (Bureau of Meteorology 1975).

Population size — Munmorah State Recreation Area

Within the Munmorah State Recreation Area plant populations were examined in detail during September 1992. Three main populations are present which are all in close proximity to one another (Table 2). It is an easy task to count the number of groups of plants along the narrow plateaux but it is difficult to decide whether plants are comprised of a number of separate individuals or are simply multi-stemmed plants. Some plants can occupy an area of 0.5 m² comprising 50–60 individual stems. In this survey, therefore, counts of plants are referred to as 'plant clumps'.

Table 2. Plant Clumps present in the Munmorah State Recreation Area. Site Numbers refer to grid co-ordinates on the Catherine Hill Bay 1:25 000 map sheet

Site	No. of plant clumps	Aspect
700275	103	North-east
	51	South-west
705281	27	North-east
	31	South-west
703268	44	East
	61	West
713273	6	South

Results

Populations of *Tetratheca juncea* could be located if conditions of topography, soil, vegetation and distance from the sea were suitable (Table 1). If one condition was unsuitable it was found that the species was not present. The Munmorah population could be related to remnant land surfaces with topography being the main determinant. Further north in the Lake Macquarie area the same habitat conditions may not necessarily apply.

The populations of *Tetratheca juncea* in the Sydney area could be expected to have occurred on similar soils, in the sense that they were infertile, shallow, stony and skeletal. Benson and Howell (1990) describe the Hawkesbury Sandstone soils in Sydney as being invariably sandy and containing rock fragments in areas of rugged slopes and plateaux. Records for locations in the Lake Macquarie and Newcastle areas (Table 3) show that it probably also occurred in drier habitats.

There are two secondary factors that appear to influence the size of the populations of *Tetratheca juncea*. These affect the abundance of plants in the population rather than the presence or absence of the population. Abundant occurrences of plants appears to be related to both the degree of canopy cover and associated understorey cover. Isolated plants occurred under a denser canopy but in low very open-woodland the abundance of plants appears to be greater. Furthermore the abundance of plants is greater in areas of sparse understorey cover in some cases. It is thought that as the cover of *Tetratheca australis* (Kangaroo Grass) increases, competition restricted the availability of sites for *Tetratheca juncea* to survive. In one area of the Munmorah State Recreation Area, the number of plants was relatively abundant where fire had burnt the understorey grass cover the previous year. The populations further north were also found to occur with open grassy understorey (Winning, 1992).

Tetratheca juncea survives fire but it is not known whether it resprouts or re-seeds. However it did flower and set seed the year following fire at Munmorah in 1991 and again in 1992. Field observations revealed that it flowered between the beginning of August through to January and sets seed beginning in October but no information is available on the effects of the species from frequent fire. Winning (1992) points out that the populations that were near Seahampton in 1986 were burnt in a May 1991

Table 3. Habitat of *T. juncea* in the Lake Macquarie–Newcastle district shown from collections in the National Herbarium of New South Wales and reported by Gutteridge Haskins and Davey Pty Ltd (1986). Rainfall Data from Bridgeman (1984)

Site	**Soils**	**Vegetation**	**Topography**	**Annual average rainfall (mm)**
Swansea	No data	*Angophora costata* complex	No data	1100
North of Lake Munmorah	Sandy soil	Open dry sclerophyll forest	No data	1160
Belmont	Sandy soil	No data	No data	1100
Raymond Terrace	Shale	Dry sclerophyll forest	No data	1031
Redhead	Aeolian sands	*Banksia aemula* heathland	Sand dunes	926
Killingworth	No data	open forest and woodland	South facing ridges and slopes	1050

fire, but could not be located in September 1991. At Jewells Swamp frequent fires (five fires in nine years) caused the plants to virtually disappear. It may be that the species requires twelve months for germination to occur following fire and to perpetuate the species it may have to be managed in relation to the degree of understorey vegetation cover although more research is needed for confirmation.

Discussion

How can long-term management be achieved, when the conservation of the species may be inadequate? The population in the Munmorah Recreation Area is less than 5.6 hectares whilst the remainder of the known population unprotected covers at least an area of 16 hectares on the narrow ridges (Figure 2). This excludes associated catchment areas. Winning (1992) recorded 1416 individuals and plant clumps for site 700275 in September 1991 compared with an estimate of 154 clumps from this survey but much of the former population may be present in road reserves. The National Parks and Wildlife Service is only able to manage the population on lands held within its authority. Remaining lands where the population occurs are privately owned and the future of *Tetratheca juncea* on those lands cannot be assured. However it is noted that there are 50 plants in the Awabakal Nature Reserve and a further 1434 plants in Glenrock State Recreation area (Winning, 1992).

The locations where the populations of *Tetratheca juncea* occur will be subject to land development and infrastructural pressures even within the Munmorah Recreation Area. Hilltops have available areas of flatlands and have been used for roads, quarries, spoil heaps, residential development and services. It appears some previous surveys have failed to identify the species and the population here has now disappeared under grassed embankments associated with this development. This development scenario combined with more frequent fire patterns is reducing the population significantly. It can only be anticipated, based on current trends, that the conservation of the Munmorah population is in doubt unless steps are taken to extend the reserved area. A population of 1000 plants for *Tetratheca juncea* may not necessarily be considered adequate to conserve the species. The plants are so thinly populated in the field over small areas with large areas between populations that they could be considered at risk until such times that a large catchment area is included with any reserve proposal.

A specific search has so far has only proceeded as far north as the Wallarah Colliery and west to Point Wolstoncroft but there are records of *Tetratheca juncea* further north and west on similar topographic features and within a similar rainfall band (Figure 1). Detailed surveys need to be undertaken to ascertain the total population and its future conservation potential. It is anticipated that hilltops in the locality with natural vegetation of the *Angophora costata* complex would contain populations of *Tetratheca juncea*. BHP Australia recently commissioned a survey on the distribution of *Tetratheca juncea* and have now found a number of new populations west of Lake Macquarie. In addition research is proceeding into cultivation using seed germination and cutting trials.

Conclusions

The occurrence of populations of *Tetratheca juncea* at Munmorah can be predicted on site conditions of topography, soil, vegetation and distance from the sea. This information will be useful for future surveys. However the future of the population at Munmorah is at risk unless planning strategies change. The vulnerable coding should remain until these planning strategies change and additional reserve area is sought to reserve the population elsewhere in a larger catchment scheme. Conserving isolated populations on a subcatchment basis may not be amenable to the survival of a population. And the lack of scientific data on the species should not be used as a basis for approving development when populations occur.

Acknowledgments

Andrew Sourry is acknowledged for his field assistance. The co-operation of Shortland Electricity, Coal and Allied Industries, and Wyong Shire Council to protect the species from damage outside the Munmorah Recreation Area is gratefully acknowledged. Also many thanks to ranger, Neil Martin, who provided details of its initial location in the Munmorah Recreation Area. Doug Benson and Geoff Winning edited and made critical comments on the manuscript, Kathy Macdonald compiled the figures, Teresa James verified my collections and the National Parks and Wildlife Service supplied details of collections from their database. Vanessa Laybutt typed the manuscript.

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Vegetation of Mulligans Flat, A.C.T.

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Abstract

Lepschi, B.J. (24 Fullwood St., Weston, Canberra, ACT, Australia 2611) 1993. Vegetation of Mulligans Flat, A.C.T.* Cunninghamia *3(1) 155–166.* The vegetation and flora of the Mulligans Flat area, A.C.T. (approximately 35°11'S 149°08'E), are described from data collected during 1988–1989, with some records from 1991 and 1992. A total of 276 species have been recorded, of which 180 are native, 93 introduced and three are persisting from cultivation.

Introduction

The Gungahlin area of the northern A.C.T. (Figure 1) is currently being developed as Canberra's next 'satellite town'. Although most of the vegetation in the area has been cleared, and the land used for livestock grazing since at least the 1850s (National Capital Development Commision (hereafter 'NCDC'), 1988a), a few remnants of the original vegetation remain. The largest and best-preserved of these is situated at Mulligans Flat, in the north-east part of the area (35°11'S 149°08'E; Figure 1). Mulligans Flat has been identified as an area of ecological significance in the A.C.T, (Frawley 1991, NCDC 1988a, b). The aim of this paper is to provide floristic data to supplement the limited information currently available on the vegetation.

The study area

For the purposes of this paper, the circumscription of the Mulligans Flat area differs slightly from the previous definition in NCDC (1988a, b), in that the southern and north-eastern borders have been extended (Figure 1), to take in areas of woodland, and the northernmost part of the 'Gungahlin Quartz Ridge' (NCDC 1988b). The Gundaroo road verge is also included, with the total study area covering 275 ha.

Mulligans Flat is currently leasehold grazing land, although stock (sheep) will be removed from the area when it gains full reserve status. The area has been utilised as grazing land since at least the 1850s; limited clearing of vegetation has taken place and a number of small stock dams (most supporting some aquatic/wetland vegetation) have been constructed. There is a shearing shed and a stock race, both of comparatively recent origin. Two vehicle tracks (used by the landholders only), run roughly east-west in the southern part of the study area (Figure 1). Little physical evidence of former habitation remains (NCDC 1988a), except for some plantings of introduced species (e.g.: **Pinus radiata*, **Photinia serrulata*) on the site of the former (closed in the 1920s) Mulligans Flat School in the extreme south-western corner of the area (see Figure 1), and tree plantings (local eucalypt species) along the former Bungendore to Ginninderra road, which was in use during the 1880s, in the extreme south of the study area.

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There is considerable support from both the scientific and general communities to have it declared a Nature Reserve (Frawley 1991).

Limited grazing and/or browsing still occurs by kangaroos and wallabies, and small numbers of rabbits. The area has been burnt by bushfires in the past, with the most recent fire in 1979 (K. Kukolic, pers. comm.).

Topography and geology

The topography is undulating, with two moderately sloping ridges (rising to approximately 680 m) running north-east to south-west separated by a flat valley (Frawley 1991). The geology consists largely of a formation known as the 'Canberra Formation', predominantly siltstone and mudstone, with a small area of the volcanic rock, dacite, on the north-eastern edge. Some quartz outcropping is also present (NCDC 1988b).

Soils of the surrounding region (and Mulligans Flat) are described generally in Gunn *et al.* (1969) and specifically for the Gungahlin area in NCDC (1988b). Shallow lithosols (often reddish in colour) are found on the ridges and slopes, with solod soils on the flatter parts of the area; these are subject to waterlogging following periods of rain (NCDC 1988a; B.J. Lepschi pers. obs.). Areas of solodic and solod solonetzic soil are present on the north-eastern edge of Mulligans Flat.

Two small ephemeral creeks and their tributaries run approximately parallel to the ridges in the valley area (with another on the areas eastern edge), and it is on these that the stock dams mentioned above are situated. Limited gully and sheet erosion is present throughout the area, associated mainly with the vehicle tracks.

Average annual rainfall at the village of Hall (35°09'S 149°03'E) approximately eight km to the west of the study area, is 700 mm, with a peak in October. Average maximum temperature at Canberra (35°15'S 149°08'E) approximately 12 km to the south of the study area, for January is 28°C and average minimum temperature in July is 0°C (information supplied by Bureau of Meteorology, Canberra).

Vegetation

Three broad vegetation types occur at Mulligans Flat, namely open-forest, woodland and grassland. These are described individually below and their approximate occurrence is shown in Figure 2.

Open-forest occurs predominantly on the shallower soils of the ridges and slopes. Dominant species are *Eucalyptus macrorhyncha*, *E. rossii* and *E. mannifera*, with some *E. goniocalyx* (this species occuring mostly towards the ridge-tops). Scattered *E. blakelyi* and *E. melliodora* occur on deeper soils on the lower slopes. There is much eucalypt regeneration and saplings are common in the understorey, along with small trees such as *Acacia dealbata*, *A. parramattensis* and *Exocarpos cupressiformis*, and shrubs including *Hibbertia obtusifolia*, *Brachyloma daphnoides*, *Melichrus urceolatus*, *Acacia gunnii*, *Daviesia* spp., *Dillwynia sericea*, and *Pultenaea* spp. The groundlayer consists of various grasses and herbs, with the following species all common: *Aristida ramosa*, *Danthonia* spp., *Dichelachne micrantha*, *Poa sieberiana* subsp. *sieberiana*, *Lomandra* spp., *Gonocarpus tetragynus*, *Hydrocotyle laxiflora*, *Wahlenbergia* spp., *Stylidium graminifolium*, and *Goodenia hederacea* subsp. *hederacea*.

Areas of actively regenerating woodland occur throughout Mulligans Flat; some of these appear to be the result of past clearing of the open forest formation (Frawley 1991, NCDC 1988b), and all of the eucalypts recorded for the latter vegetation type

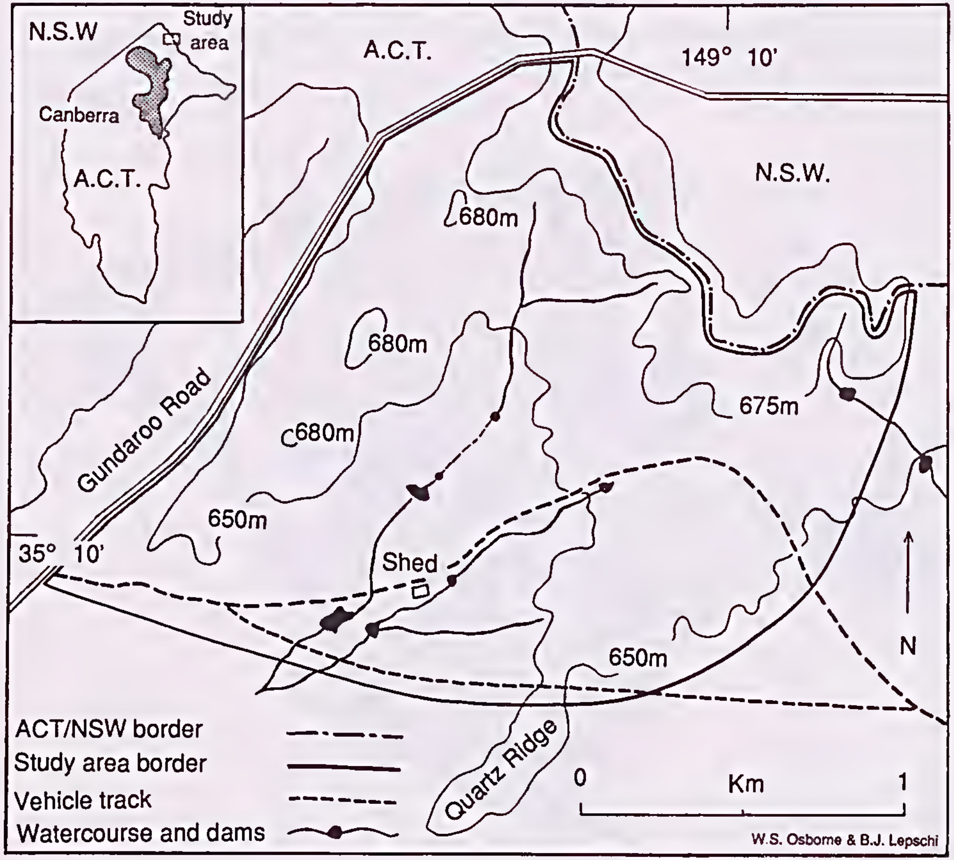

Figure 1. Map of study area showing major features and location (inset)

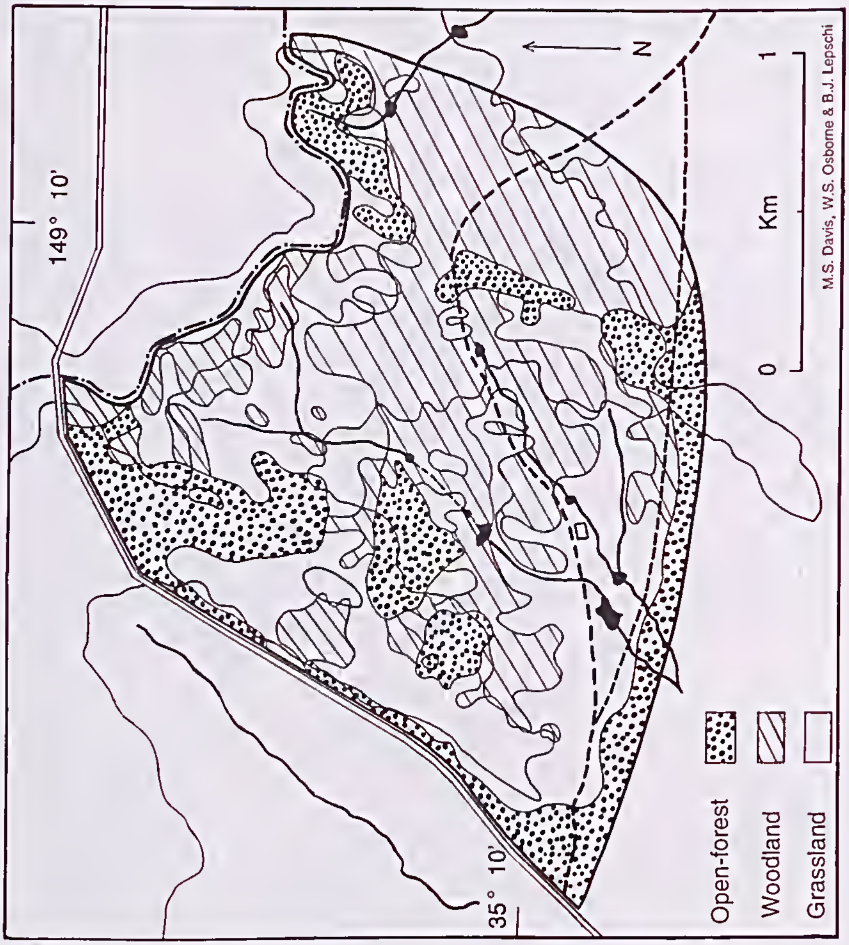

Figure 2. Vegetation of Mulligans Flat

can be found in the woodland areas. On flatter sites with deeper soil, woodland dominated by *Eucalyptus blakelyi* and *E. melliodora* is found, with scattered *E. bridgesiana* and *E. rubida* subsp. *rubida*. The latter is frequent along the creek bordering an area of open grassland near the shearing shed. The understorey is generally sparse, with eucalypt saplings and scattered stands of *Acacia* spp. (mainly *A. dealbata*) and shrubs including *Hibbertia obtusifolia, Lissanthe strigosa, Melichrus urceolatus*, * *Rosa rubiginosa, Daviesia genistifolia*, and *Cryptandra amara* var. *longiflora*. Grasses and herbs again make up the groundcover, with *Aristida ramosa, Bothriochloa macra, Danthonia* spp., *Eragrostis benthamii, Panicum effusum* var. *effusum, Stipa bigeniculata, S. scabra* subsp. *falcata, Themeda australis, Wurmbea dioica* subsp. *dioica, Drosera peltata, Glycine tabacina*, * *Trifolium arvense*, * *T. dubium, Hydrocotyle laxiflora, Wahlenbergia* spp., **Hypochaeris* spp., *Solenogyne dominii*, and *Vittadinia muelleri* all commonly occurring.

Patches of grassland occur throughout the area; *Panicum effusum* var. *effusum* and *Themeda australis* are common components, particularly where only light grazing has taken place. Other frequent species include *Danthonia* spp., *Eragrostis benthamii, Stipa bigeniculata*, and *S. scabra* subsp. *falcata*. In disturbed sites or areas subjected to heavier grazing, **Aira* spp., *Bothriochloa macra*, and *Chloris truncata* are also common.

Species list

All species recorded by the author on (generally monthly) visits to the area during the period May 1988 to August 1989 and again in April 1991 and April and November 1992 are listed (Table 1). It was not possible to cover the entire area on each occasion. Also included are species recorded by M.S. Davis during survey work for Scott and Furphy Pty Ltd, in January 1992. Family concepts (except for the recognition of the Lobeliaceae) and nomenclature follow. Hnatiuk (1990); where a name differs from the latter, the author and relevant reference is cited. Vouchers were generally not collected; those that were are lodged in the Australian National Herbarium, CSIRO, Canberra (CANB; authors collections) and the Herbarium of the Australian National Botanic Garden, Canberra (CBG; M.S. Davis's collections).

The list is not exhaustive, and many more species can be expected, particularly when stock have been removed from the area.

Table 1. List of plant species recorded at Mulligans Flat, A.C.T. (1988–1992).

Species not indigenous to Australia are marked with an asterisk (*); indigenous species not native to the Canberra area are marked with a hash symbol (#).

For species recorded by M.S. Davis (see above), the abbreviation 'MD' is included after the name in brackets.

A subjective indication of frequency and abundance (based on that used by Helman *et al* 1988) is given for each species. Abbreviations used are:

W – widespread
L – localised
C – common
U – uncommon
R – rare
P – persisting from former cultivation, but not naturalised

PTERIDOPHYTES

Adiantaceae

Cheilanthes austrotenuifolia	WC
Cheilanthes sieberi subsp. *sieberi* (MD)	LU

Ophioglossaceae

Ophioglossum lusitanicum subsp. *coriaceum* (see Wilson 1990)	LC

GYMNOSPERMS

Pinaceae

**Pinus radiata*	LR

ANGIOSPERMS

MONOCOTYLEDONS

Cyperaceae

Carex inversa	LU
Cyperus sanguinolentus	LC
Eleocharis acuta	LC
Schoenus apogon	LC

Eriocaulaceae

Eriocaulon scariosum	LR

Hydrocharitaceae

Ottelia ovalifolia	LC

Iridaceae

?* *Sisyrinchium* sp. A (sensu Wilson in prep.; = *S. micranthum* Cav. (see Cooke 1986))	LR

Juncaceae

Juncus australis	WU
**Juncus articulatus*	LU
Juncus bufonius	WU
**Juncus capitatus*	WU
Juncus filicaulis	WC
Juncus holoschoenus	LC
Juncus homalocaulis	WU
Juncus sarophorus	LC
Juncus subsecundus	WC
Juncus vaginatus	LU
Luzula flaccida	WC

Liliaceae

Bulbine bulbosa	LR
Burchardia umbellata	LR
Caesia calliantha	LR
Dianella revoluta subsp. *revoluta*	LR
Dichopogon fimbriatus	LU
Hypoxis hygrometrica var. *hygrometrica*	LC
Hypoxis vaginata var. *vaginata*	LU
Thysanotus tuberosus subsp. *tuberosus*	LR
Tricoryne elatior	WU
Wurmbea dioica subsp. *dioica*	WC

Orchidaceae

Dipodium punctatum (MD)	LR
Diuris sp.	LR
Eriochilus cucullatus	LR
Microtis unifolia	LC
Thelymitra pauciflora (MD)	LR

Poaceae

Agrostis avenacea var. *avenacea*	LC
**Aira cupaniana*	WC
**Aira elegantissima*	WC
Amphibromus nervosus	LC
Aristida ramosa R. Br. (see Simon 1992)	WC
**Avena barbata*	LR
**Avena fatua*	LC
Bothriochloa macra	WC
**Briza maxima*	LC
**Briza minor*	WU
**Bromus catharticus*	LC
**Bromus diandrus*	LU
**Bromus hordeaceus* subsp. *molliformis*	LR
**Bromus madritensis*	LR
Chloris truncata	WC
Cynodon dactylon	WU
**Cynosurus echinatus*	LC
Danthonia auriculata (MD)	LU
Danthonia caespitosa	WC
Danthonia carphoides var. *carphoides*	WC
Danthonia laevis (MD)	WC
Danthonia monticola (MD)	LU
Danthonia pallida	WC
Danthonia penicillata (MD)	WC
Danthonia pilosa var. *pilosa*	WU

Poaceae (cont'd)

Danthonia racemosa var. _racemosa_ (MD)	WU
Dichelachne micrantha	LC
Elymus scaber var. _scaber_ (sensu Jacobs in prep.)	WU
Enneapogon nigricans	WU
Eragrostis benthamii	WU
*_Hordeum leporinum_ Link.(sensu Jacobs in prep.)	LR
*_Lolium perenne_	LU
*_Lolium rigidum_	LU
Microlaena stipoides var. _stipoides_	WU
*_Nassella trichotoma_	LR
Panicum effusum var. _effusum_	WC
*_Paspalum dilatatum_	LC
*_Phalaris aquatica_	LU
*_Phleum pratense_	LU
Poa sieberiana var. _sieberiana_	LC
*_Rostraria cristata_ (MD)	LR
*_Setaria gracilis_ var. _pauciseta_	LC
Stipa bigeniculata	WC
Stipa densiflora	LU
Stipa scabra subsp. _falcata_	WC
Themeda australis (R.Br) Stapf. (sensu Jacobs in prep.)	WC
*_Vulpia bromoides_	WU

Potamogetonaceae

Potamogeton tricarinatus	LC

Xanthorrhoeaceae

Lomandra filiformis subsp. _coriacea_	WC
Lomandra multiflora subsp. _multiflora_ (see Lee and Macfarlane 1986)	WU

DICOTYLEDONS

Amaranthaceae

Alternanthera denticulata	LU
Alternanthera sp. A (sensu Jacobs & Lapinpuro 1990)	WU

Apiaceae

Daucus glochidiatus (s. lat.)	WU
Eryngium rostratum Cav. (see Powell & Wiecek 1992)	LU
Hydrocotyle laxiflora	WC
Hydrocotyle peduncularis (s. lat.)	LC

Apocynaceae

*_Vinca major_	P

Asteraceae

*_Arctotheca calendula_	WU
Brachycome rigidula	WU
Calocephalus citreus	LR
*_Carduus pycnocephalus_	LR
*_Carthamus lanatus_	LU
Cassinia aculeata	LR
Cassinia longifolia	LR

Asteraceae (cont'd)

Cassinia quinquefaria	WU
Centipeda cunninghamii	LC
Centipeda minima	LU
*_Chondrilla juncea_	LR
Chrysocephalum apiculatum (Labill.) Steetz Steetz (s. lat.) (syn. _Helichrysum apiculatum_ (Labill.) DC.; see Anderberg 1991)	WU
Chrysocephalum semipapposum (Labill.) Steetz (s. lat.) (syn. _Helichrysum semipapposum_ (Labill.) DC.; see Anderberg 1991)	LR
*_Cirsium vulgare_	WC
*_Conyza albida_	LR
Cotula australis	WU
Craspedia variabilis Everett & Doust (see Everett & Doust 1992)	LC
Cymbonotus preissianus	WU
Euchiton gymnocephalus (DC.) A. Anderb. (syn. _Gnaphalium gymnocephalum_ DC.; see Anderberg 1991)	LC
Euchiton sphaericus (Willd.) A. Anderb. (syn. _Gnaphalium sphaericum_ Willd.; see Anderberg 1991)	WU
*_Gnaphalium americanum_ Miller (sensu Everett 1992)	LU
*_Hypochaeris glabra_	WU
*_Hypochaeris radicata_	WC
Isoetopsis graminifolia	LR
Leptorhynchos squamatus	LR
*_Logfia gallica_	LC
Microseris lanceolata (s. lat.)	WU
Pseudognaphalium luteo-album	WU
Senecio quadridentatus	WU
Solenogyne dominii	WC
Solenogyne gunnii	LU
*_Sonchus asper_ subsp. _glaucescens_	LU
*_Sonchus oleraceus_	WU
*_Taraxacum_ sp. agg.	WU
*_Tolpis umbellata_	WU
*_Tragopogon dubius_	LR
Triptilodiscus pygmaeus	WC
Vittadinia cuneata var. _cuneata_	WU
Vittadinia muelleri	WC

Boraginaceae

Cynoglossum suaveolens	LR
*_Echium plantagineum_	LC
*_Myosotis discolor_	WU

Brassicaceae

*_Hirschfeldia incana_	LU
*_Lepidium africanum_	LU
*_Sisymbrium officinale_	LC

Campanulaceae

Wahlenbergia communis	WC
Wahlenbergia graniticola (MD)	LR
Wahlenbergia multicaulis (MD)	LR
Wahlenbergia stricta	WC

Table 1. (cont'd)

Caryophyllaceae	
**Moenchia erecta*	WU
**Paronychia brasiliana*	LU
**Petrorhagia nanteuilii*	WU
**Polycarpon tetraphyllum*	LU
Scleranthus diander	LR
**Silene gallica* var. *gallica*	LR
**Spergularia rubra*	WU
**Stellaria media*	LU
Stellaria pungens	WU
Chenopodiaceae	
**Chenopodium album*	LR
Chenopodium pumilio	LC
Einadia nutans subsp. *nutans*	WU
Clusiaceae	
Hypericum gramineum	WC
Convolvulaceae	
Convolvulus erubescens	WU
Dichondra repens	LU
Crassulaceae	
Crassula sieberiana subsp. *tetramera*	LC
Dilleniaceae	
Hibbertia obtusifolia (s. lat.)	WC
Droseraceae	
Drosera peltata	WC
Epacridaceae	
Astroloma humifusum	LU
Brachyloma daphnoides	LC
Leucopogon virgatus	WU
Lissanthe strigosa	WU
Melichrus urceolatus (bushy form with hairy, acute sepals and acuminate petals; see Burbidge & Gray 1970)	WC
Euphorbiaceae	
Chamaesyce drummondii (Boiss) Hassall (see James & Harden 1990)	WU
Poranthera microphylla	WU
Fabaceae	
Bossiaea buxifolia	LU
Bossiaea prostrata	LU
**Cytisus* sp.	P
Daviesia genistifolia	WU
Daviesia leptophylla	LU
Daviesia mimosoides R. Br. subsp. *mimosoides* (see Crisp 1991)	LR
Desmodium brachypodum (MD)	LR
Desmodium varians	LU
Dillwynia sericea	LC
Glycine clandestina (s. lat.)	WU
Glycine tabacina (s. lat.)	WU
Gompholobium huegelii (MD)	LR
Hardenbergia violacea	LU
Fabaceae (cont'd)	
Hovea linearis	LR
Indigofera australis	WU
**Medicago arabica*	WU
**Medicago polymorpha* (see Weston 1991a)	LR
**Medicago sativa*	LR
Psoralea adscendens	LR
Pultenaea microphylla Sieber ex DC. (see Weston 1991b)	LU
Pultenaea procumbens	WC
**Trifolium angustifolium*	LU
**Trifolium arvense*	WC
**Trifolium campestre*	WU
**Trifolium dubium*	WU
**Trifolium glomeratum*	WR
**Trifolium repens*	WU
**Trifolium striatum* (MD)	LR
**Trifolium subterraneum*	LU
**Vicia sativa* subsp. *sativa*	LR
Gentianaceae	
**Centaurium erythraea*	WC
Sebaea ovata	LU
Geraniaceae	
**Erodium botrys*	LR
**Erodium cicutarium*	LC
**Geranium molle*	LC
Geranium solanderi var. *solanderi*	WU
Goodeniaceae	
Goodenia hederacea Smith subsp. *hederacea* (See Carolin 1992)	WC
Velleia paradoxa	WU
Haloragaceae	
Haloragis heterophylla	WC
Gonocarpus tetragynus	WC
Myriophyllum crispatum	LC
Lamiaceae	
**Marrubium vulgare*	LR
Mentha diemenica (MD)	LR
Mentha sp. aff. *diemenica* (sensu Burbidge & Gray 1970)	WU
**Salvia verbenaca*	LR
Linaceae	
**Linum trigynum*	WR
Lobeliaceae	
Isotoma fluviatilis	LC
Loranthaceae	
Amyema miquelii	WC
Amyema pendulum subsp. *pendulum*	LR
Lythraceae	
Lythrum hyssopifolia	WU

Malaceae	
*_Crataegus monogyna_ (see Harden & Rodd 1990b)	LR
*_Pyracantha angustifolia_	LR
Malvaceae	
*_Modiola caroliniana_	LU
Mimosaceae	
# _Acacia baileyana_	LR
Acacia dealbata	WC
Acacia gunnii	LU
Acacia implexa	LU
Acacia mearnsii	LU
Acacia parramattensis	LC
Myrtaceae	
Eucalyptus blakelyi	WC
Eucalyptus bridgesiana	LU
Eucalyptus dives (MD)	LU
Eucalyptus goniocalyx	LC
Eucalyptus macrorhyncha Benth. (see Brooker and Kleinig 1990)	WC
Eucalyptus mannifera Mudie (see Brooker & Kleinig 1990)	WC
Eucalyptus melliodora	WC
Eucalyptus rossii	LU
Eucalyptus rubida Deane & Maiden subsp. _rubida_ (see Hill and Johnson 1991)	WU
Onagraceae	
Epilobium billardierianum subsp. _cinereum_	WU
Orobanchaceae	
*_Orobanche minor_	LR
Oxalidaceae	
*_Oxalis_ sp. A (see Conn 1992)	LU
Oxalis exilis	LR
Oxalis perennans	WU
Papaveraceae	
*_Papaver somniferum_ subsp. _setigerum_ (see Jacobs 1990)	LR
Plantaginaceae	
*_Plantago coronopus_ subsp. _commutata_	LC
Plantago gaudichaudii	LR
*_Plantago lanceolata_	WU
Plantago varia (sensu Briggs _et al_ 1977)	LC
Polygonaceae	
Persicaria prostrata	LC
*_Polygonum arenastrum_	LU
*_Rumex acetosella_	WU
Rumex brownii	WC
*_Rumex crispus_	LC
Portulacaceae	
Montia fontana subsp. ?_chondrosperma_	LC
Portulaca oleracea (sensu West 1990)	LC
Primulaceae	
*_Anagallis arvensis_ (red-flowered form; see Makinson 1990)	WU
Ranunculaceae	
Ranunculus lappaceus	WU
Ranunculus sessiliflorus var. _sessiliflorus_	LR
Rhamnaceae	
Cryptandra amara var. _longiflora_	WU
Rosaceae	
Acaena novae-zelandiae	LR
Acaena ovina (s. str.; see Harden & Rodd 1990a)	WC
*_Photinia serrulata_	P
*_Prunus_ sp.	LR
*_Rosa rubiginosa_	WU
Rubiaceae	
Asperula conferta	WU
*_Galium divaricatum_	WU
Galium gaudichaudii	LR
*_Sherardia arvensis_	LC
Santalaceae	
Exocarpos cupressiformis	WU
Scrophulariaceae	
*_Linaria pelisseriana_	WU
*_Parentucellia latifolia_	LU
*_Verbascum thapsus_	LR
*_Veronica arvensis_	LR
Solanaceae	
*_Solanum nigrum_	LR
Stylidaceae	
Stylidium graminifolium	LC
Thymelaeaceae	
Pimelea curviflora var. _sericea_	WU
Violaceae	
Viola betonicifolia (see James 1990)	LR

Discussion

The vegetation and floristics of Mulligans Flat show similarities to other comparable areas in the A.C.T., such as Black Mountain Reserve (Gray & McKee 1969) and the Ainslie–Majura Reserve (Ingwersen *et al.* 1974), although neither of these reserves contain such large areas of woodland or grassland as at Mulligans Flat. The presence of species such as *Acacia parramattensis, Pultenaea microphylla, Eucalyptus goniocalyx* and possibly (see below), *Cheiranthera cyanea,* point to an association with vegetation of similar areas to the north of Mulligans Flat (i.e.; the northern part of the Southern Tablelands of N.S.W.), where these species are more abundant and widespread than in the A.C.T. (B.J. Lepschi unpubl.).

Acacia parramattensis, Bossiaea prostrata, Desmodium brachypodum and *Eucalyptus goniocalyx,* four species recorded from the study area, are regarded as uncommon in the A.C.T. (Burbidge & Gray 1970; Gilmour *et al.* 1987; NCDC 1984; NCDC 1988; National Capital Planning Authority 1992). A fifth, *Cheiranthera cyanea,* was recorded as occurring at Mulligans Flat by Burbidge & Gray (1970), Frawley (1991) and NCDC (1988a), but was not located during this study (or in recent survey work by M.S. Davis). It is very inconspicuous when not in flower, and may well have been overlooked; it is known to occur on the Gundaroo road verge in N.S.W. approximately 1.5 km to the north-east of the study area, and is fairly common in the Gunning and Yass districts, approximately 30 km to the north (B.J. Lepschi unpubl.).

Two introduced herbs, **Linum trigynum* and **Logfia gallica* are of regional significance. **Linum trigynum* (*Lepschi & Davis 918* (AD, BRI, CANB, CHR, HO, K, MEL, NSW)) does not appear to have been previously recorded for the A.C.T. or the southern tablelands of N.S.W. (Gardner 1992), although it has since (early 1993) been collected at a few other sites in the Canberra–Queanbeyan area (B.J. Lepschi unpubl.). **Logfia gallica* (*Lepschi 866, Lepschi & Davis 919* (both CANB, MEL, NSW)) represents a new record for both the A.C.T. and N.S.W. (Brown 1992).

Introduced species comprise 34% (93 spp; #*Acacia baileyana* is here regarded as introduced) of the 276 species recorded from Mulligans Flat; they occur throughout the area, but are most prevalent in the woodland and grassland formations, which have been subject to greater disturbance than the open forest areas. Grossly disturbed sites such as the Gundaroo road verge, the area around the shearing shed, the old school site and the verges of the vehicle tracks are particularly heavily invaded, with major weed species such as **Marrubium vulgare,* **Echium plantagineum,* and **Chondrilla juncea* largely confined to these sites at present.

**Rosa rubiginosa* is the only woody weed of any importance in the area, with other potentially invasive species (e.g.: **Crataegus monogyna,* **Pyracantha angustifolia* and #*Acacia baileyana*) currently of limited distribution and abundance.

Of the ornamental plantings on the old Mulligans Flat School site, only two species, **Pinus radiata* and #*Acacia baileyana* show signs of spreading. **P. radiata* is present as scattered small plants and seedlings, mainly in the vicinity of the parent plants, while *A. baileyana* occurs predominantly as mature plants in a few localities within the study area.

Mulligans Flat is an area of great conservation significance; low altitude woodland and grassland communities are very poorly represented in conservation reserves within the ACT and surrounding areas. Those that have been reserved are predominantly in the southern part of the Canberra area (lowland communities do not extend far beyond the current southern edge of Canberra), and Mulligans Flat represents the northernmost reservation of these communities in the ACT. It is also the only reserve of any substantial size in the Gungahlin area of Canberra.

The relatively light clearing and grazing activity on Mulligans Flat has resulted in some of the best preserved areas of lowland open-forest, woodland and grassland in the ACT, which apart from their botanical importance also provide valuable habitat for a diverse vertebrate fauna (Frawley 1991; Taylor & Canberra Ornithologists Group 1992; W.S. Osborne pers. comm.).

Acknowledgments

Lyn Craven, Maxine Davis, Frank Ingwersen and Will Osborne all commented on the manuscript; Maxine kindly made available her unpublished survey data for the Mulligans Flat area and provided information for the preparation of Figure 2. Will also drew the draft for the figures and provided much appreciated encouragement and assistance.

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Floristic lists of New South Wales (IV)

D.H. Benson and S.C. Melrose

Abstract

Benson, D.H. & Melrose. S.C. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, NSW, Australia 2000) 1993. Floristic lists of New South Wales (IV). Cunninghamia *3 (1): 167–213.* An annotated bibliography of 202 floristic lists mainly from the 1986–1992 period, has been collated. The bibliography continues the format of earlier listings, with notes on the locality (including 1:250 000 map sheet and additional Local Government Area occurrence), extent of species list and ecological information. Papers are numbered and ordered according to the botanical subdivisions of New South Wales, authors and dates of compilation.

Introduction

Floristic lists are often the only source of botanical information for a particular area and may serve as a useful starting point for more detailed study. Such lists may be used for general comparisons of the vegetation of different localities, or that of the same locality at different times. The preparation of an increasing number of environmental impact studies and plans of management in recent years has prompted a corresponding interest in floristic lists. This, the fourth annotated bibliography compiled by the Royal Botanic Gardens, follows the works of Pickard (1972), Bryant & Benson (1981) and Keith (1988), bringing the total of references in the series to 572.

Types of lists included

Similar criteria to those of the earlier bibliographies have been adopted and the journals listed by Bryant & Benson (1981) have been scanned. Most lists are from the 1986–1992 period, though a number of older, previously overlooked lists have been included. The lists range from regional floras to brief lists of predominating species and may or may not include ecological notes on the vegetation, the environment or the abundance of the species. They also vary considerably with regard to the size of the area surveyed and the precision with which this is defined, as well as completeness and the reliability of identifications. Nomenclature may be out of date, depending on when the lists were compiled.

The bibliography includes both published and unpublished material, copies of the latter being held at the Royal Botanic Gardens Library and available on request from the librarian.

Arrangement of the bibliography

As in Keith (1988), the lists are arranged according to the botanical subdivision in which they occur. A map of the botanical subdivisions of New South Wales is provided in the end papers. These are explained in full by Anderson (1961). Where a list covers more than one botanical subdivision it is listed under the major subdivision and cross-referenced in other relevant subdivisions. Within the subdivisions the lists

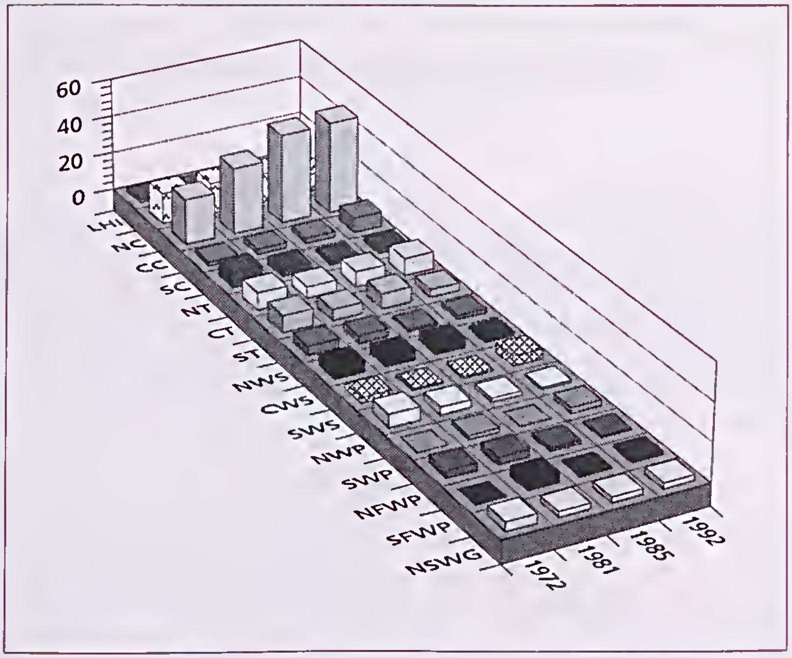

Figure 1. Changes in percentage of floristic lists for botanical subdivisions for bibliographies since 1972. See table 1 for figures.

Table 1. Percentage of floristic lists for each of the botanical sudivisions of N.S.W. Data from Pickard (1972), Bryant & Benson (1981), Keith (1988,) and this paper.

	1972	1981	1985	1993
Lord Howe Island	2	1	3	0
North Coast	16	16	15	9
Central Coast	24	35	47	49
South Coast	2	3	3	8
Northern Tablelands	8	4	2	3
Central Tablelands	9	6	8	9
Southern Tablelands	9	6	8	4
North Western Slopes	5	4	1	2
Central Western Slopes	6	5	5	2
South Western Slopes	3	1	1	5
North Western Plains	7	4	2	1
South Western Plains	0	2	0	3
North Far Western Plains	4	4	2	2
South Far Western Plains	0	5	1	2
New South Wales – General	5	3	3	3
Total %	100	99	101	100
Total number of lists	290	182	219	173

are arranged alphabetically by author and then by date. This arrangement is intended to facilitate searching by the geographical area of interest. As a further spacial index, the name(s) of the relevant 1:250 000 map sheet(s) and Local Government Areas (LGA) are given at the end of each reference. The numbering of references follows on from Keith (1988). Table 1 shows reference numbers for each of the botanical subdivisions.

Each entry in the bibliography is listed with its author, its date of publication, or compilation if unpublished, and its title. Annotations include the approximate number of species, their arrangement in the list and references to any ecological notes provided on abundance, habitat, soil type, plant communities, etc.

The list of 202 references is given below.

Results

There are 202 floristic lists in the current bibliography, in line with the earlier bibliographies (Table 1). The annual rate of accumulation of lists for 1986–1992 (7 years: 29/year) is down on the 1981–1985 period (5 years: 44/year) but up on the 1972–1981 period (9 years: 20/year).

The proportions of lists for the various botanical subdivisions (Figure 1, Table 1) show an increase in the percentage from the South Western Slopes and the South Coast, both areas needing further botanical documentation, but a decrease in the proportion from the North Coast. There is relatively little change for the other subdivisions. The majority of lists are still from the Central Coast (48%), reflecting the continuing interest in Sydney's urban bushland, and it is disappointing to see the very low numbers of lists presently available for other subdivisions particularly on the Western Slopes and Plains. This may not, however be a complete picture of the amount of work being done in these areas, as there are currently a number of major surveys, e.g., by the National Parks and Wildlife Service, amassing large databases from extensive site data that is never published. Hopefully this data will eventually become available, but until then, published lists will remain the main source of data to many workers.

Access to species list data is important to those involved in natural area management, and we urge people with lists that they would like included in forthcoming bibliographies to forward them to the Ecology Section. Unpublished lists will be lodged in the Royal Botanic Gardens Library and made available on request. In compiling lists for such purposes, accurate identifications and site localities are essential. Long, unannotated lists covering large, poorly defined areas are less useful. Such lists should be recorded either by sites or by plant communities and should be accompanied, where possible, by descriptions of the relevant plant communities, together with accurate locational information. Data on the relative abundance of the different species may also be worthwhile. There is also an increasing need for ecological observations on species, such as fire responses, fruiting periods, seed dispersal and growing periods. Such observations can be readily integrated with a species list.

General references

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Journals searched

The following journals were searched, together with a number of occasional publications for the period 1986 to 1992.

Australian Journal of Botany
Australian Journal of Ecology
Australian Journal of Marine & Freshwater Research
Australian Natural History
Australian Plants
Cunninghamia
Ecological Monographs
Ecology
ECOS
Forestry Commission NSW Research Notes
Journal of Ecology
Journal of Soil Conservation NSW
National Parks Journal (National Parks Association of NSW)
Proceedings of the Linnean Society of NSW
Telopea
The Victorian Naturalist
The Orchadian
Wetlands (Australia)

Floristic lists of New South Wales (IV)

LORD HOWE ISLAND

Nil

NORTH COAST

370 BENSON, J.S. (1981)

Tomaree National Park proposal

NSW National Parks & Wildlife Service (unpub.)

Discussion of land use and vegetation. Floristic lists for Tomaree Head and Morna Point, and Yaccaba Head rainforest (compiled by M. Dodkin and A. Clough).

1:250 000 topographic map: Newcastle

LGA: Port Stephens

371 BENSON, J.S. (1982)

Jasper Nature Reserve proposal

NSW National Parks & Wildlife Service (unpub.)

Discussion of riverfront vegetation including floristic list.

1:250 000 topographic map: Hastings

LGA: Hastings

372 BENSON, J.S. (1985)
Watchinbark Creek Nature Reserve proposal
NSW National Parks & Wildlife Service (unpub.)
Discussion of serpentinite vegetation including floristic list.
1:250 000 topographic map: Hastings
LGA: Gloucester

373 BENSON, J.S. (1986)
Proposed Timbarra River National Park
NSW National Parks & Wildlife Service (unpub.)
Vegetation and fauna described. Floristic list included.
1:250 000 topographic map: Warwick
LGA: Casino

374 BENSON, J.S. & HAGER, T. (1993)
The distribution and habitat of *Eucalyptus dunnii* (Myrtaceae) (Dunn's White Gum) in New South Wales.
Cunninghamia 3(1): 123–145
Survey of rare tree species including list of associated species
1:250 000 topographic map: Dorrigo, Warwick
LGA: Coffs Harbour, Nymboida, Kyogle

375 CRAWFORD, I. (1992)
The vegetation of the Singleton Army Area, November–December 1991
Prepared for CSIRO Division of Water Resources (unpub.)
Describes vegetation in terms of grassed areas, Forest Red Gum woodland remnants, Swamp Oak riverine forest, and Spotted Gum – Ironbark open forest. Lists about 250 species, both native and exotic, community recorded and voucher specimen numbers. Area is about 120 square km. south of Singleton between Wittingham and the Broken Back Range.
1:250 000 topographic map: Singleton
LGA: Singleton

376 FORESTRY COMMISSION (1990)
Flora species of the Bulahdelah Management Area
Pacific Highway (State Highway No.10) Bulahdelah-Coolongolook Deviation: Environmental Impact Statement Working Papers (Roads and Traffic Authority: Sydney)
Appendix A contains a list of 400 species in four communities in the Buladelah area: rainforest, wet sclerophyll forest, dry sclerophyll forest, and woodland/shrubland.
1:250 000 topographic map: Newcastle
LGA: Great Lakes

377 FOX, M.D. (1986)

The effect of fire frequency on the structure and floristic composition of a wood land understory

Australian Journal of Ecology 11(1): 77–85

The study showed that obligate seedling regenerators may be lost in frequently burnt areas, while vegetative regenerators and short lived obligate seedling regenerators may be lost in infreqently burnt areas. Thirty-eight understory species are listed with the mode of regeneration after fire.

1:250 000 topographic map: Newcastle

LGA: Port Stephens

378 GRIFFITH, S.J. (1989)

Rainforest vegetation within and about Woko National Park and Camel's Hump Nature Reserve

Prepared for N.S.W. National Parks & Wildlife Service (unpub.)

Describes rainforest vegetation in the area and its conservation status. Appendices list over 300 rainforest species with abundance measures for 48 sites, site and inspection point data, and species and subspecies at their known southern limit of distribution in the North Coast botanical subdivision.

1:250 000 topographic map: Hastings

LGA: Gloucester

379 GRIFFITH, S.J. (1992)

Vegetation of Crowdy Bay National Park

NSW National Parks & Wildlife Service (draft report)

Detailed vegetation descriptions with vegetation map (1:12 500) and dicussion of significant species and vegetation management. List of 500 native species in part B.

1:250 000 topographic map: Hastings

LGA: Hastings

380 HUNTER REGION BOTANIC GARDENS LTD (1986)

The Hunter Region Botanic Gardens Management Plan

The Hunter Region Botanic Gardens Ltd.

A listing of 300 species by family occurring naturally on or near site. Common names included.

1:250 000 topographic map: Newcastle

LGA: Newcastle

381 NEW SOUTH WALES DEPARTMENT OF PLANNING AND ENVIRONMENT

Macleay – Apsley Land Use Study

NSW National Parks & Wildlife Service submission (unpub.)

Major report of area now Oxley Wild Rivers National Park. List of 800 vascular plant species provided based on 200 sampling sites. Land systems mapped.

1:250 000 topographic map: Dorrigo

LGA: Dumaresq, Walcha

382 PENMAN, S., RANKIN, E., & MOYE, J. (1987)

Rare and endangered native orchid species survey

The Orchadian 9(1): 5–9

Lists 47 species and the degree of rarity and their location. Map of sites in the drainage basin of the Richmond River.

1:250 000 topographic map: Tweed Heads, Warwick, Maclean

LGA: Richmond River, Kyogle, Tweed

383 PRESSEY, R.L. & GRIFFITH, S.J. (1987)

Coastal wetlands and associated communities Tweed Shire, Northern New South Wales

NSW National Parks and Wildlife Service (unpub.)

A systematic listing of 768 species. Growth form is designated as are the communities in which the species are found.

1:250 000 topographic map: Tweed Heads

LGA: Tweed

384 PRESSEY, R.L. (1989)

Wetlands of the Lower Clarence Floodplain, Northern Coastal New South Wales

Proceedings of the Linnean Society of New South Wales 111(3): 143–155

List of 70 plants. Includes occurrence in open water wetlands by the number occuring, percent total number, total area occupied and percent of total wetland area.

1:250 000 topographic map: Grafton

LGA: Copmanhurst

385 PRESSEY, R.L. (1989)

Wetlands of the Lower Macleay Floodplain,N orthern Coastal New South Wales

Proceedings of the Linnean Society of New South Wales 111(3): 157–168

Lists 118 plants with occurrence in open water wetlands, by number occurring, percent total number, total area occupied and percent of total wetland area.

1:250 000 topographic map: Dorrigo, Hastings, Coffs Harbour

LGA: Kempsey

386 RAINFOREST CONSERVATION SOCIETY INC (1992)

The Central Eastern Rainforests of Australia

World Heritage Nomination (draft)

Describes rainforest lands proposed for world heritage listing in N.S.W. and Queensland with sections on geology and geomorphology, soils, climate, bioclimates, vegetation, flora and fauna, with detailed justification for world heritage listing in terms of scientific values. Includes list of rare plant species, together with list of about 1700 native vascular plant species indicating occurence at each of the nominated sites which include Border Ranges National Park, Limpinwood Nature Reserve, Numinbah N.R., Mt Warning N.P., Nightcap N.P., Mt Nothofagus F.R., Iluka N.R., Washpool N.P., Gibraltar Range N.P., Dorrigo N.P., New England N.P., Mt Hyland N.R., Werrikimbe N.P., Mt Seaview N.R., Banda Banda Flora Reserve, Barrington Tops N.P.

1:250 000 topographic map: Tweed Heads, Warwick, Grafton, Maclean, Dorrigo, Hastings, Tamworth, Newcastle

LGA: Kempsey, Kyogle, Tweed, Byron, Copmanhurst, Maclean, Nymboida, Tenterfield, Severn, Bellingen, Coffs Harbour, Walcha, Dungog, Gloucester, Singleton, Scone, Kempsey, Lismore, Hastings

387 SMITH, P., BENSON, J.S., DICK, R., DODKIN, M & ANDREW, D. (1984)

Proposed Mount Neville Nature Reserve

NSW National Parks & Wildlife Service (unpub.)

Plant communities described with vegetation map (1:25 000).

1:250 000 topographic map: Grafton

LGA: Casino

388 WILLIAMS, G. (1990)

Riverine rainforest remnants in the Manning valley

Wetlands (Australia) 9(2): 68–75

Describes three previously unrecognised riverine rainforest remnants with list of tree species and comparisons with lists for Wingham and Coocumbac Island Nature Reserves.

1:250 000 topographic map: Hastings

LGA: Greater Taree

389 WILLIAMS, G. & ADAM, P. (1991)

Rainforest remnants on headlands in the Manning Valley: their composition and conservation significance

Wetlands (Australia) 11(1): 21–30

A preliminary list of 94 native trees and shrubs within remnant rainforest communities is given for the headlands of Crowdy Head, Saltwater, Redhead, and Black Head.

1:250 000 topographic map: Hastings

LGA: Greater Taree

CENTRAL COAST

390 AKKERSDYK, P. (1985)

Plant list for Jannali Reserve

(unpub.)

A checklist of 222 plants found in the area.

1:250 000 topographic map: Wollongong

LGA: Sutherland

391 AKKERSDYK, P. (1989)

Kurnell Peninsula plant list

(unpub.)

Contains 340 species found in the area with common names. Includes a list of 66 weeds.

1:250 000 topographic map: Wollongong

LGA: Sutherland

392 ANON (1989)

Native species recorded in Sheldon Forest Turramurra

(unpub.)

An alphabetic listing of 86 species in the forest. Same have been examined for adaptations helpful in surviving drought and fire and results are noted.

1:250 000 topographic map: Sydney

LGA: Ku-ring-gai

393 ANON (no date)

Nepean Dam environmental survey – plant list (appendix 1)

Prepared for Water Board (unpub.)

List of 136 species by family indicating location on plateau, old spoil deposit or valley floor. Exotic species noted.

1:250 000 topographic map: Wollongong

LGA: Wollongong

394 ANON, (probably 1980s)

Species list of plants at Elizabeth Farm, Parramatta

Probably prepared for Historic Houses Trust (unpub.)

A checklist of 145 species and their location on the Farm. Map included. Gives a description of whether they occur as a bulb, tree, shrub, succulent, annual or perennial. Common names given.

1:250 000 topographic map: Sydney

LGA: Parramatta

395 ANOS – Warringah Inc.

The Native Orchids of Warringah Shire 1988–1989

NSW National Parks & Wildlife Service

A list of 57 terrestrial and 8 epiphytic orchids. Map and brief description of the area, vegetation and all orchids occurring in that area.

1:250 000 topographic map: Sydney

LGA: Warringah

396 BENSON, D.H. (1984)

List of plants growing on Bar Island, Hawkesbury River

Royal Botanic Gardens, Sydney (unpub.)

Listing of 100 species by family growing on Bar Island. Exotic species included.

1:250 000 topographic map: Sydney

LGA: Hornsby

397 BENSON, D.H. (1987)

Survey of vegetation associated with huts at Crater Cove, Dobroyd Head

Royal Botanic Gardens Sydney (unpub.)

An assessment of exotic species both naturalised and planted in relation to the huts and to the natural vegetation associated with the site. List of 50 exotic species recorded. Map included.

1:250 000 topographic map: Sydney

LGA: Manly

398 BENSON, D.H. (1989)

Native species recorded at Prospect Reservoir

Royal Botanic Gardens Sydney (unpub.)

List of 99 species. Rare species include: *Acacia pubescens, Pultenaea microphylla, Daviesia genistifolia, Lotus australis, Oxylobium scandens, Ranunculus inundatus, R. lappaceus, R. sessiliflorus* and *Scutellaria humilis.*

1:250 000 topographic map: Sydney

LGA: Blacktown Council

399 BENSON, D.H. (1989)

Natural bushland on Macquarie University Campus, North Ryde

Royal Botanic Gardens Sydney (unpub.)

A checklist of 95 species in this remnant Turpentine – Ironbark forest which is characteristic of shale areas in the Ryde area before industrial development.

1:250 000 topographic map: Sydney

LGA: Ryde

400 BENSON, D.H. (1989)

Native species recorded in Banksmeadow heath on sand dune at Banksmeadow Public School

Royal Botanic Gardens Sydney (unpub.)

This remnant of the Eastern Suburbs Banksia Scrub contains 20 indigenous species. The scrub once covered 7000 ha between Waterloo and Botany Bay. Recommendations for conservation are made.

1:250 000 topographic map: Sydney

LGA: Botany

401 BENSON, D.H. (1990)

Vegetation of the Driftway Reserve, Hawkesbury Campus, University of Western Sydney — an important remnant of floodplain forest and freshwater swamp

Royal Botanic Gardens Sydney (unpub.)

Description of two wetland areas and associated forest and recommending long term protection. List of about 150 native and exotic species indicating vegetation type, compiled from lists by Peter Lister and Erica Morris, L. McDougall and D. Benson, and J. Stricker. (see also Lister & Morris 1992)

1:250 000 topographic map: Sydney

LGA: Hawkesbury

402 BENSON, D.H. (1992)

Remnant native bushland at Campsie

Royal Botanic Gardens Sydney (unpub.)

Contains list of 42 species of native vegetation from remnant of Turpentine – Ironbark Forest on Wianamatta Shale soil. The site occupies 0.5 ha on the banks of the Cooks River at the end of Third Avenue.

1:250 000 topographic map: Sydney

LGA: Canterbury

403 BENSON, D.H. (1992)

The natural vegetation of the Penrith 1:100 000 map sheet

Cunninghamia 2(4): 541–596

Describes and maps 18 plant communities and discusses rare and endangered species, regional affinities and conservation of vegetation. Includes species lists for Grose Vale "limestone" and Native Vineyard, Cobbitty. For full species list for area see Benson & McDougall (1991).

1:250 000 topographic map: Sydney

LGA: Bankstown, Baulkham Hills, Blacktown, Blue Mountains, Fairfield, Hawkesbury, Holroyd, Liverpool, Parramatta, Penrith, Wollondilly

404 BENSON, D. H., HOWELL, J. & McDOUGALL, L. (1989)

Vegetation of Big Bay Island, Marramarra Creek, Hawkesbury River, New South Wales

Royal Botanic Gardens, Sydney (unpub.)

A list of 88 species arranged alphabetically by family with seed dispersal mechanism noted. Notes on vegetation included. The island, unnamed but called Big Bay Island here, is part of Marramarra National Park.

1:250 000 topographic map: Sydney

LGA: Hornsby

405 BENSON, D. & HOWELL, J. (1990)

Taken for granted: the bushland of Sydney and its suburbs

Kangaroo Press: Kenthurst

This book describes eight main vegetation types in the County of Cumberland, their presettlement extent and the changes that have taken place since 1788. Includes lists of the common species of Sydney's vegetation types.

1:250 000 topographic maps: Sydney, Wollongong

LGA: Ashfield, Auburn, Bankstown, Baulkham Hills, Blacktown, Botany, Burwood, Camden, Campbelltown, Canterbury, Concord, Drummoyne, Fairfield, Hawkesbury, Holroyd, Hornsby, Hunters Hill, Hurstville, Kogarah, Ku-ring-gai, Lane Cove, Leichhardt, Liverpool, Manly, Marrickville, Mosman, North Sydney, Parramatta, Penrith, Randwick, Rockdale, Ryde, South Sydney, Strathfield, Sutherland, Sydney City, Warringah, Waverley, Willoughby, Woollahra

406 BENSON, D.H. AND KEITH, D.A. (1990)

The natural vegetation of the Wallerawang 1: 100 000 map sheet

Cunninghamia 2(2) 305–335

The composition and extent of the present natural vegetation on the Wallerawang 1: 100 000 map sheet 8931 (lat. 30°00'–33°30'S, long. 150°00'–150°30'E) are described and mapped. There is a listing of 670 species by family, with a description of the community structure and associated environmental factors contained within 18 map units and 29 plant communities.

1:250 000 topographic map: Sydney

LGA: Greater Lithgow

407 BENSON, D.H., THOMAS, J. & BURKETT, J. (1990)

The natural vegetation of Bents Basin State Recreation Area

Cunninghamia 2(2): 223–262

Contains a systematic listing of 362 species found in the Bents Basin listed by the number of species found in 24 communities. Contains species of particular significance with notes on habitat/location, significance and potential threat. Also lists exotic species, their abundance and distribution.

1:250 000 topographic map: Sydney

LGA: Liverpool, Wollondilly

408 BENSON, D. & MCDOUGALL, L. (1991)

Rare bushland plants of Western Sydney

Royal Botanic Gardens, Sydney

Describes c. 950 species of plants in the area with their occurrence in 5 major vegetation types with an estimate of abundance, their occurrence by local government area, and the conservation status of each species — whether conserved, vulnerable or extinct. 373 vulnerable species and 17 extinct species are listed.

1:250 000 topographic maps: Sydney, Wollongong

LGA: Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Hawkesbury, Holroyd, Liverpool, Parramatta, Penrith

409 BENSON, J.S. (1985)

Vegetation survey of Riverstone Meatworks property, South Windsor: vegetation remnant on Tertiary alluvium

NSW National Parks & Wildlife Service (unpub.)

Floristic lists and vegetation map for area now Windsor Downs Nature Reserve.

1:250 000 topographic map: Sydney

LGA: Blacktown, Hawkesbury

410 BROCKOFF, J.O., & ALLAWAY, W.G.(1989)

Vesicular-arbuscular mycorrhizal fungi in natural vegetation and sand-mined dunes at Bridge Hill, New South Wales

Wetlands (Australia) 8(2): 47–54

Forty-seven of the 52 vascular species in both mined and unmined sites at Bridge Hill contained vesicular-arbuscular mycorrhizas. Bridge Hill is located in the Myall Lakes National Park (32°24'S, 152°30'E).

1:250 000 topographic map: Newcastle

LGA: Great Lakes

411 BUCHANAN, R.A. (1989)

Pied Currawongs (*Strepera graculina*): their diet and role in weed dispersal in suburban Sydney, New South Wales.

Proceedings of the Linnean Society of New South Wales 111: 241–255

Lists 46 species of seed found in the pellets regurgitated by pied currawongs from a garden in Thornleigh and the highest frequency in any one month. Commo names given as well as introduced species. Also lists additional fruits and seeds reported in previous studies which are additional to those recorded at Thornleigh.

1:250 000 topographic map: Sydney

LGA: Hornsby

412 CLARKE, P.J. & BENSON, D.H. (1986a)

Vegetation survey of Dharug National Park

Royal Botanic Gardens, Sydney (unpub.)

Contains vegetation analyses, descriptions, management and recommendations with listing of 700 species.

1:250 000 topographic map: Sydney

LGA: Gosford

413 CLARKE, P.J. & BENSON, D.H. (1986b)

Provisional floristic list for Wamberal Lagoon Nature Reserve

Royal Botanic Gardens, Sydney (unpub.)

Lists about 100 native and exotic species.

1:250 000 topographic map: Sydney

LGA: Gosford

414 CLARKE, P.J. & BENSON, D.H. (1987a)

Vegetation survey for proposed Nature Reserve at Mt. White – Mt Olive area

Royal Botanic Gardens, Sydney (unpub.)

Describes vegetation found on different geological units, with significant vegetation, plus rare and restricted species. Lists 450 species including rainforest species in the Gosford area with recommendations for management of the area.

1:250 000 topographic map: Sydney

LGA: Gosford

415 CLARKE, P.J. & BENSON, D.H. (1987b)

Vegetation survey of Lane Cove River State Recreation Area.

Royal Botanic Gardens, Sydney (unpub.)

Discusses the setting and vegetation patterns, types of species found in different landscape units, management and recommendations. Lists 351 species indiginous to the area and 133 weeds. Maps of vegetation & landscapes.

1:250 000 topographic map: Sydney

LGA: Lane Cove, Ryde, Hornsby

416 CLARKE, P.J. & BENSON, D.H. (1988)

The natural vegetation of Homebush Bay — two hundred years of changes.

Lists 64 species recorded in the estuarine wetlands at Homebush Bay and 105 species recorded in Eucalypt forest on Navy land at Silverwater.

Wetlands (Australia) 8(1): 3–15.

1:250 000 topographic map: Sydney

LGA: Auburn, Concord

417 COVENY, R.G. & McDOUGALL, L. (1990)

Plant species on Long Island Nature Reserve, Hawkesbury River

Royal Botanic Gardens, Sydney (unpub.)

Lists over 200 species from Long Island Nature Reserve near Brooklyn. Includes exotic species.

1:250 000 topographic map: Sydney

LGA: Hornsby

418 DARRACOT, J., McBARRON, E. & HATCH, M. (1987)

Yellow Rock, NSW, period 1920–1940

Shellharbour Municipal Library (unpub.)

Descriptive listing of many plant species growing at Yellow Rock near Albion Park in the period 1920–1940. Part of an historical account and includes references to fauna and flora both native and horticultural. Refer to species list in *Cunninghamia* (1981) 1(1): 59–71.

1:250 000 topographic map: Wollongong

LGA: Shellharbour

419 DODSON, J.R. (no date)

Widening of Forest Way vegetation survey: Ralston Ave to Mona Vale Road

Survey undertaken by Gunninah Consultants for Roads & Traffic Authority (unpub.)

List of 150 native species by family. Assesses natural vegetation in a 20m transect along Forest Way, Belrose for proposed widening of road. (See also Kodela 1990).

1:250 000 topographic map: Sydney

LGA: Warringah

420 DOLMAN, G.S. (1987)

Dynamics of Sydney's urban bushland from fine resolution pollen analysis

PhD Thesis, Australian National University (unpub.)

Contains a list of 300 species for the 48 ha recreation reserve surrounding Lake Parramatta (Lat. 33°47'30"S, Long. 151°00'30"E). Life forms, habitat types, and species presence during this survey and two previous surveys are noted. Exotics included.

1:250 000 topographic map: Sydney

LGA: Parramatta

421 FORD, A. (1989)

The sclerophyllous flora of Wollemi National Park

(unpub.)

An alphabetical checklist of 267 species from 4 localities in Wollemi National Park, Fern-tree gully, Mount Darcy, Mount Baker, and Dunns Swamp. Dunns Swamp listing includes two undescribed *Prostanthera* species.

1:250 000 topographic map: Singleton

LGA: Rylstone, Muswellbrook

422 FORD, A.J. (1990)

Flora list of the Bare Rock Bluff area, Wollemi National Park.

(unpub.)

List of 200 species from a single visit in Febrary, 1990. The survey area is south of Bare Rock Bluff but not the Kekeelbon Mountains. Locality map. Coricudgy 1:25 000 map sheet.

1:250 000 topographic map: Singleton

LGA: Muswellbrook

423 FRIENDS OF BRADLEY BUSHLAND RESERVE (1990)

Draft plan of management for Bradley Bushland Reserve and Wildflower Walk, Mosman

Friends of Bradley Bushland Reserve, (unpub.)

This draft management plan includes appended species lists of 166 native plants and 100 exotic plants found in the Reserve. Map of the Reserve is included.

1:250 000 topographic map: Sydney

LGA: Mosman

424 GIBSON, C. (1992)

Prospect Reservoir native plant species list

(unpub.)

Contains 190 species listed by family. Site occurrence ratings, site conservation status, and regional conservation status are provided.

1:250 000 topographic map: Sydney

LGA: Blacktown

425 GIBSON, C. & MILLER, R. (1988)
Indigenous plant species list for Lansdowne Park
(unpub.)
Lists 158 plants growing in Lansdowne Park, Bankstown. Several species considered important because they are becoming rare. *Leichhardtia leptophylla* is considered very rare.
1:250 000 topographic sheet: Sydney
LGA: Bankstown

426 GIBSON, C. AND MILLER, R. (1988)
Species list for Norfolk Reserve and Lot 2, D.P. 546653, Greenacre
(unpub.)
List of 100 species by family.
1:250 000 topographic sheet: Sydney
LGA: Bankstown

427 GREENING AUSTRALIA URBAN BUSH MANAGEMENT UNIT (1991)
Baulkham Hills Shire bushland survey
Greening Australia: Sydney
List of trees and some groundcover species for parks in Castle Hill – Baulkham Hills area with recommendations on bushland management.
1:250 000 topographic sheet: Sydney
LGA: Baulkham Hills

428 HALL, A.R. (1989)
Native species at Malabar Bush (Anzac Rifle Range)
(unpub.)
An alphabetical listing of 200 species. Location according to eastern headland or western escarpment.
1:250 000 topographic map: Sydney
LGA: Randwick

429 JAMES, T.A. & KODELA, P.G. (1992)
Species list for Little Cattai Creek and tributary creeks
Royal Botanic Gardens, Sydney (unpub.)
List of about 200 native species for a relatively undisturbed sandstone area west of Maroota.
1:250 000 topographic map: Sydney
LGA: Baulkham Hills

430 KEITH, D. (1992)
List of vascular plants found at Caloola Pass
NSW National Parks & Wildlife Service (unpub.)

List of 60 native species found in layered tall mesic forest with *Eucalyptus fastigata* and *Eucalyptus smithii on* the escarpment talus slope

1:250 000 topographic map: Wollongong

LGA: Kiama

431 KODELA, P.G. (1990)

Widening of Forest Way vegetation survey: Hews Parade to Ralston Ave

Survey undertaken by Gunninah Consultants, for Roads & Traffic Authority (unpub.)

List of 170 species by family. Exotic species and noxious plants are noted. Assesses natural and planted vegetation in 20 m transect along Forest Way, Belrose for proposed widening of road. (See also Dodson undated).

1:250 000 topographic map: Sydney

LGA: Warringah

432 KODELA, P.G. & ROWE, R.R.M. (1990)

Survey of vegetation along New Line Road between Shepherds Drive and Purchase Road.

Survey undertaken by Gunninah Consultants, for Roads & Traffic Authority (unpub.)

Assesses remnant native vegetation on Wianamatta Shale and points out conservation and amenity significance. Lists 100 native and exotic species, basal area of large trees and species suitable for regeneration in the shale forest.

1:250 000 topographic map: Sydney

LGA: Hornsby

433 KUBIAK, P.J. (1989)

Floristic list of natural vegetation — Pages and Kittys Creeks, North Ryde.

(unpub.)

Lists 260 species arranged alphabetically by family indicating presence on each creek.

1:250 000 topographic map: Sydney

LGA: Ryde

434 KUBIAK, P.J. (1990)

Endemic species of Lady Fuller Park in the Austinmer – Thirroul Area.

(unpub.)

A list of 370 indiginous species with of location as to clifftops or below clifftops.

1:250 000 topographic map: Wollongong

LGA: Wollongong

435 KUBIAK, P.J. (1991)

Knapsack Creek area, Glenbrook — floristic list (excluding exotic species)

(unpub.)

Lists 269 native species for the area bounded by Mitchells Pass Rd, the Great Western Highway, and Olivet and Barnet Sts. Some plants designated as apparently rare or uncommon in the area.

1:250 000 topographic map: Sydney

LGA: Blue Mountains

436 KUBIAK, P.J. (1992)

Middle Harbour catchment area — floristic list

(unpub.)

List of 560 naturally occurring native species from the Middle Harbour catchment, upstream of Spit Bridge. Species are listed by family and designated as widespread, occurring in scattered locations, apparently rare, apparently uncommon, or as garden escapees.

1:250 000 topographic map: Sydney

LGA: Willoughby, Warringah, Ku-ring-gai

437 KUBIAK, P.J. (1992b)

Narrabeen Lagoon catchment area — floristic list (excluding exotic species)

(unpub.)

Lists about 400 native species with brief comments on abundance.

1:250 000 topographic map: Sydney

LGA: Warringah

438 KUBIAK, P.J. (1993)

North Ryde Park, Cressy Rd, Pittwater Rd/Magdala Rd, North Ryde — floristic list (remnant native vegetation)

(unpub.)

Lists about 40 native species with brief comments on abundance and condition.

1:250 000 topographic map: Sydney

LGA: Ryde

439 KUBIAK, P.J. (1993b)

Dalrymple Hay Nature Reserve, Mona Vale Rd/Rosedale Rd, St Ives — floristic list (excluding exotic species)

(unpub.)

Lists about 120 native species with brief comments on rarity. 1:250 000 topographic map: Sydney

LGA: Ku-ring-gai

440 KUBIAK, P.J. (1993c)

Wallumatta Nature Reserve, Cressy Rd/Twin Rd, North Ryde — floristic list (excluding exotic species)

(unpub.)

Lists about 150 native species with brief comments on rarity.

1:250 000 topographic map: Sydney

LGA: Ryde

441 KUBIAK, P.J. (1993d)

Frenchs Forest Showground — Glen St/Pringle Ave/Blackbutts Rd, Frenchs Forest Ryde — floristic list (remnant native vegetation)

(unpub.)

Lists about 75 native species.

1:250 000 topographic map: Sydney

LGA: Warringah

442 LAI, M. (1991-2)

Plant species lists — Parsley Bay Reserve, Woollahra

(unpub.)

Includes separate lists of 100 native plant species (July 1991), and 100 exotic weed species with comments on removal (March 1992)

1:250 000 topographic map: Sydney

LGA: Woollahra

443 LEMBIT, R. (1985)

Vegetation survey — Prospect Creek

(Unpub.)

Includes list of 180 plants found within four sections extending from Widemere Rd. in the northwest to the Granville–Cabramatta railway line in the south-east. Common names and exotic species are included.

1:250 000 topographic map: Sydney

LGA: Fairfield

444 LEMBIT, R. (1987?)

Plant species from proposed extraction area at Menangle

(Unpub.)

Part of a flora and fauna study conducted by Mount King Ecological Surveys for the proposed sand and loam extraction works at Menangle Park. Table 1 contains a list of 120 plants present in forest or cleared habitats. Common names and exotic species are included.

1:250 000 topographic map: Wollongong

LGA: Wollondilly

445 LEMBIT, R. (no date)

Floristic list for selected cemeteries in the Penrith area

(Unpub.)

List of 120 species from St Thomas Church, Mulgoa; St Mary Magdalene Church, St Marys; and the Castlereagh General Cemetery. Exotic species are noted.

1:250 000 topographic map: Sydney
LGA: Penrith

446 LEMBIT, R. (no date)
Floristic list for proposed Phillip Parkway, Rooty Hill
(Unpub.)
Listing 100 plant species by family, exotic species noted.
1:250 000 topographic map: Sydney
LGA: Blacktown

447 LISTER, P.R. & MORRIS, E. (1990)
A census of the flora of the Hawkesbury Reserve
University of Western Sydney (unpub.)
A list of approximately 200 species including Bryophytes, ferns and angiosperms for two portions of the Reserve, which is part of the Hawkesbury Campus of the University. (See also Benson 1990)
1:250 000 topographic map: Sydney
LGA: Hawkesbury

448 McDOUGALL, L. & CONROY, R. (1989)
Preliminary checklist of plant species in Mitchell Park
(unpub.)
List of 260 species listed alphabetically by family. Introduced species noted. Now part of Cattai National Park. Wilberforce 1:25 000 map sheet
1:250 000 topographic map: Sydney
LGA: Hawkesbury

449 McDOUGALL, L. & CONROY, R. (1988-1990)
Species list for Davidson Park State Recreation Area
Ku-ring-gai Chase National Park (unpub.)
Checklist of 450 species arranged alphabetically by family. Introduced species indicated.
1:250 000 topographic map: Sydney
LGA: Ku-ring-gai, Warringah

450 McRAE, R.H.D. (1990)
Vegetation of Bouddi Peninsula, New South Wales
Cunninghamia 2(2): 263–293
Vegetation survey and map. Listing of 360 species with growth forms and vegetation areas types. Exotic species noted.
1:250 000 topographic map: Sydney
LGA: Gosford

451 MORRIS, E.C., SKELTON, N.J. & DURHAM, S.J. (1990)

Vegetation of three headlands of the Central Coast of New South Wales — Norah, Wamberal and Wybung Heads

Wetlands (Australia) 9(2): 49–67.

The vegetation of these headlands is described in terms of up to 12 vegetation types from closed-forest to *Themeda* grassland. Species, both native and exotic, are listed for each headland by vegetation type.

1:250 000 topographic map: Sydney

LGA: Wyong

452 NIEUWENHUIS, A. (1987)

The effect of fire frequency on the sclerophyll vegetation of the West Head, New South Wales

Australian Journal of Ecology 12(4): 373–385

Fifteen pairs of sites at West Head were assessed to research the effect of fire frequency on the relative abundance of obligate-seeders and vegetative-regenerators. An appended species list of 92 plants for each pair of sites is included indicating whether they occurred in frequently burnt or infrequently burnt sites.

1:250 000 topographic map: Sydney

LGA: Warringah

453 PAYNE, R. (no date)

Species lists for Nunns Creek Gullies

(unpub.)

A systematic listing of 95 plants located in the Erina area (33°27'S, 151°23'E). Common names given. *Endiandra discolor, Parsonsia velutina, Ripogonum fawcettianium* and *Calanthe triplecata* are found in the area and are species of special conserva tion significance to the area.

1:250 000 topographic map: Sydney

LGA: Gosford

454 PAYNE, R. (1988)

Provisional species list — Crommelin Native Arboretum, naturally occurring species (unpub.)

List of 160 species in two plant communities arranged by family. Introduced species and common names are noted (grasses not included). Located at Pearl Beach.

1:250 000 topographic map: Sydney

LGA: Gosford

455 PAYNE, R. (1988)

Vegetation report for a proposed sandstone extraction industry at Mount White.

(unpub.)

Lists 260 species by plant community in a previously worked quarry which is now a proposed sandstone extraction site. This listing is provisional due to the late winter timing of the survey. Probably representative of tree and shrub species but lacking in herbaceous and monocotyledonous species. Nature conservation capability assessment included which lists representativeness of vegetative community, rare or endangered species and disturbance. Topography, geology, soils, and hydrology of the area are described as is vegetation structure. Maps of the communities are included.

1:250 000 topographic map: Sydney

LGA: Gosford

456 PAYNE, R. (1989)

Vegetation report for Hallstrom Park (Flat Rock Reserve) Willoughby

Report No.2 (unpub.)

List of 128 species in the reserve. Map provided. Common names given. Some plants are marked as species of special significance in the area: *Platycerium bifurcatum, Asplenium australasicum, Austromyrtus tenuifolia, Leucopogon amplexicaule.*

1:250 000 topographic map: Sydney

LGA: Willoughby

457 PAYNE, R. (1989)

Vegetation assessment & strategy plan for reserve to be located on the Green Point Headland, Lake Macquarie

(unpub.)

Contains a species list of 286 plants with their location in 7 communities. Map included.

1:250 000 topographic map: Sydney

LGA: Lake Macquarie

458 PAYNE, R. (1989)

Melaleuca Swamp forest at Key Street, Toukley

Report prepared for Wyong Shire Council (unpub.)

List of 80 species occurring in a Melaleuca Swamp Open-forest on Quaternary alluvium with notes on structure, habitat and dominant species. Common names and introduced species noted. Faunal list included.

1:250 000 topographic map: Sydney

LGA: Wyong

459 PAYNE, R. (1989)

Species list of Ettymalong Swamp, Umina Beach, NSW.

(unpub.)

A list of 300 species with notes on vegetation structure, habitat, distribution and dominant species. Naturalised weeds along creek included (30% of species). Includes common names. Maps of rank weed growth & natural vegetation pockets. Ettymalong Swamp has been reclaimed with resultant flooding downstream.

Study undertaken to assess vegetation with view of widening the creek. Broken Bay 1:25 000 map sheet.

1:250 000 topographic map: Sydney

LGA: Gosford

460 PAYNE, R. (1989)

Botanical assessment of Porters Creek Swamp with relation to the urban release proposals of Wyong Shire

(unpub.)

Description of vegetation, topography, geology and soils. Includes a nature conservation capability assessment of the flora which lists representative species, rare and endangered plants and disturbances. 168 species listed by family. Introduced species indicated. Photos of vegetation communities and maps included.

1:250 000 topographic map: Sydney

LGA: Wyong

461 PAYNE, R. (1989)

Littoral rainforest on North Entrance Peninsula: extent of *Syzygium paniculatum*

(unpub.)

Lists 25 plants from remnant rainforest. Special reference to the extent of *Syzygium paniculatum*, *Ficus fraseri*, and *Euroschinus falcata*. Map and photographs.

1:250 000 topographic map: Sydney

LGA: Wyong

462 PAYNE, R. (1990)

A survey of three creeks in the Wadalba West catchment

(unpub.)

Includes 147 species in two plant communities. Exotic plants noted. Site map.

1:250 000 topographic map: Sydney

LGA: Wyong

463 PAYNE, R. (1990)

Vegetation survey for north-east by-pass road. Section: Etna Street to Bradys Gully Road, Alignment no 1. Report no 2.

(unpub.)

List of 140 species for open-forest on Terrigal Formation geology near Gosford. Introduced species and common names included.

1:250 000 topographic map: Sydney

LGA: Gosford

464 PAYNE, R. (1990)

Vegetation survey for north-east by-pass road. Section: Lushington Street to Terama Place, Alignment no 4. Report no 3.

(unpub.)

List of about 200 species for three plant communities near Gosford: woodland on Hawkesbury Sandstone and forest, and open-forest on Terrigal Formation geology. Includes introduced species. Rare or significant plants are identified as are noxious plants.

1:250 000 topographic map: Sydney

LGA: Gosford

465 PAYNE, R. (1990)

Vegetation survey of the main Wedderburn Plateau and minor creek systems

(unpub.)

Contains an appended species list of 230 plants found in three vegetation communities located within the Wedderburn Plateau incorporating Pheasants Creek and Georges River sub catchments. Introduced species noted and common names given. Map of area.

1:250 000 topographic map: Sydney

LGA: Campbelltown

466 PAYNE, R. (1990)

Species list for Eastern Creek

(unpub.)

List of 90 plants found at Eastern Creek between the motorway and the water supply pipeline.

1:250 000 topographic map: Sydney

LGA: Blacktown

467 PAYNE, R. (1991)

Flora and fauna survey: Bensville near Gosford, New South Wales

(unpub.)

Contains 253 species in seven plant communities. Introduced species, and plants of special significance noted. Site map and plant community map.

1:250 000 topographic map: Sydney

LGA: Gosford

468 PAYNE, R. (1991)

Flora and fauna investigation at Yattalunga near Gosford, New South Wales

(unpub.)

Includes 144 species of native and introduced species in four plant communities.

1:250 000 topographic map: Sydney

LGA: Gosford

469 PAYNE, R. (1991)

Botanical investigation of proposed upgrading of Wilfred Barrett Drive North Entrance Peninsula

(unpub.)

Contains 198 species in five plant communities. Includes exotic species. The endangered plant *Syzygium paniculatum* occurs in the area. Map.

1:250 000 topographic map: Sydney

LGA: Wyong

470 PAYNE, R. (1991)

Erina Valley flora and fauna survey

(unpub.)

134 species are contained in two plant communities in this area. Map.
Exotic species noted.

1:250 000 topographic map: Sydney

LGA: Gosford

471 PAYNE, R. (1992)

Enterprise Drive environmental study

(unpub.)

Includes list of 245 species found within three vegetation communities on two geological formations. Map.

1:250 000 topographic map: Sydney

LGA: Wyong

472 PAYNE, R. (1992)

Statement of environmental effects and landscape design report for a proposed paintball facility at Lot 4 DP773173 Bunning Creek Road

(Unpub.)

Plant species list contains 187 species which includes the rare, *Callistemon shiressii.* Map.

1:250 000 topographic map: Sydney

LGA: Wyong

473 PERKINS, I. (1990)

Vegetation survey of Chullora Railway Workshops

(unpub.)

Lists 100 indigenous plant species located in the workshop area. The area contains remnant areas of natural vegetation typical of the Cumberland Plain vegetation associations.

1:250 000 topographic map: Sydney

LGA: Bankstown

474 ROSE, S. (1986)

A vegetation survey of the Nepean River near Menangle

Elizabeth Macarthur Agricultural Institute (unpub.)

Describes vegetation along the western bank of the River between Menangle Rd Crossing and Bergins Weir outlining significant species. Lists about 100 native species together with notes on occurrence. Also lists adjacent Orchard Paddock

exotic plantings.
1:250 000 topographic map: Wollongong
LGA: Camden

475 ROSE, S. (1990)
Elizabeth Macarthur Agricultural Institute Botanical Plant Collection (1985–1990)
Elizabeth Macarthur Agricultural Institute (unpub.)
Lists 600 species in the herbarium collection for specimens collected on the property, formerly part of Camden Park. Listings are by botanical and common name with family noted. Includes 248 species indigenous to the Institute grouped by growth form or habitat and 26 species found in lagoons and dams.
1:250 000 topographic map: Wollongong
LGA: Camden

476 S.G.A.P.(Society for Growing Australian Plants) Sutherland (1982)
Plant list Menai No.2 area
(unpub.)
Checklist of 178 species.
1:250 000 topographic map: Wollongong
LGA: Sutherland

477 S.G.A.P.(Society for Growing Australian Plants) Sutherland (1983)
Plant list, Towra Point
(unpub.)
A checklist of 200 species found in the area.
1:250 000 topographic map: Wollongong
LGA: Sutherland

478 SHERINGHAM, P.R., & SANDERS J.M. (1993)
Vegetation survey of Garigal National Park and surrounding Crown Lands
NSW National Parks & Wildlife Service report
Detailed vegetation survey describing and mapping (1:25 000) 21 plant communities and listing 300 indigenous plant species with notes on significant species and reserve management recommendations. Located near Narrabeen.
1:250 000 topographic map: Sydney
LGA: Warringah

479 SMITH, P. & SMITH, J. (1990)
Vegetation and fauna of Berowra Valley Bushland Park
Report prepared for Hornsby Shire Council
Describes 17 plant communities and lists over 500 native and exotic species with abundance and plant community. Discusses rare species and management considerations. Vegetation map and fauna lists.
1:250 000 topographic map: Sydney
LGA: Hornsby

480 STRICKER, J. (no date)

Interim list of plant species identified from Health Department land, Red Gum Avenue, Pennant Hills, N.S.W.

Nature Conservation Council of NSW (unpub.)

Lists 100 species with common names. Protected species noted. Divided into trees, shrubs and herbs.

1:250 000 topographic map: Sydney

LGA: Hornsby

481 SULMAN, F. (1914)

Excursions [to Glenbrook Creek]

Australian Naturalist 3:11

Brief list of the more notable species seen at Glenbrook Creek.

1:250 000 topographic map: Sydney

LGA: Blue Mountains

482 THOMAS, D (1990)

Rainforest conservation status in the Metropolitan and Woronora catchment areas

Water Board: Sydney

Describes rainforest in the catchment areas of Cataract, Cordeaux, Avon, Nepean and Woronora dams with detailed species lists for 31 sites.

1:250 000 topographic map: Wollongong

LGA: Wingecarribee, Wollondilly, Wollongong

483 THOMAS, J. & BENSON, D.H. (updated 1991)

Vegetation survey of Muogamarra Nature Reserve

Royal Botanic Gardens, Sydney (unpub.)

A reprinting with minor revisions including additions to the species list.

1:250 000 topographic map: Sydney

LGA: Hornsby

484 WINFIELD, D. (1991)

Mullet Creek report, appendices 1 and 2

Student exercise (unpub)

Lists of 180 native and 50 exotic species for Mullet Creek, south of Ingleside Park, Warriewood.

1:250 000 topographic map: Sydney

LGA: Warringah

485 WINNING, G. (1990)

Lake Macquarie Natural Areas Study

(unpub.)

Contains descriptions of the plant communities, factors affecting distribution, significant flora and conservation. There is a vegetation map and a structural

classification of plant communities.
1:250 000 topographic map: Sydney
LGA: Lake Macquarie

SOUTH COAST

486 ALBRECHT, D. (1986a)
Plant species growing in the vicinity of the summit of Mount Imlay
Royal Botanic Gardens, Melbourne (unpub.)
Alphabetical listing by family of 89 species, designated either east and south-east or west of the summit.
1:250 000 topographic map: Mallacoota
LGA: Bega Valley

487 ALBRECHT, D. (1986b)
Vascular flora of Narrabarba Hill
Royal Botanic Gardens, Melbourne (unpub.)
93 species arranged alphabetically by family with location: vicinity, *Eucalyptus sieberi* forest or summit.
East of Princes Highway, South of Wonboyn River. Eden 1:100 000 map sheet, grid ref. 518 719.
1:250 000 topographic map: Mallacoota
LGA: Bega Valley

488 ALBRECHT, D. (1986c)
Vascular flora of the Nethercote Falls area, Nullica State Forest
Royal Botanic Gardens, Melbourne (unpub.)
260 species listed alphabetically by family.
Nullica State Forest is above the Towamba River between Upper Kiah and Nethercote.
1:250 000 topographic map: Mallacoota
LGA: Bega Valley

489 BENSON, J.S., ANDREWS, D. & CAMPBELL, D. (1986)
Cudmirrah sand dunes: report on flora and fauna
NSW National Parks & Wildlife Service (unpub.)
Floristic and faunal lists and vegetation description for area near Sussex Inlet.
1:250 000 topographic map: Ulladulla
LGA: Shoalhaven

490 BINNS, D. (1988)
A preliminary list of vascular plant species for far south-eastern New South Wales
Forestry Commission of NSW research paper No 4
Lists c. 1000 species of vascular plants in the Eden native forest management area by geographic distribution and provides a risk assessment, occurrence and

comments. Contains an appended list of species by site.

1:250 000 topographic maps: Bega, Mallacoota

LGA: Bega Valley

491 BINNS, D.L. & KAVANAGH, R.P. (1990a)

Flora and fauna survey of Nalbaugh State Forest (part), Bombala District, Eden Region, south-eastern New South Wales

Forest Resources Series No 9 (Forestry Commission of NSW: Sydney)

Detailed description of 20 vegetation communities with list of 265 native and five naturalised plant species.

1:250 000 topographic maps: Bega

LGA: Bombala

492 BINNS, D.L. & KAVANAGH, R.P. (1990b)

Flora and fauna survey, Nullica State Forest (part), Eden District, Eden Region, southe-astern New South Wales

Forest Resources Series No 10 (Forestry Commission of NSW: Sydney)

Detailed description of 27 vegetation communities with list of 370 native and nine naturalised plant species.

1:250 000 topographic maps: Bega

LGA: Bega Valley

493 CHIPPENDALE, G.M. (1991)

Broulee plants

Nature in Eurobodalla (Journal of the Eurobodalla Natural History Society) (4): 40–44

Describes the successional communities of Broulee with a list of 60 species designated for location on island, forest, dunes and beach.

1:250 000 topographic map: Ulladulla

LGA: Eurobodalla

494 CRAWFORD, I. (1992)

Plant list for Wadbilliga NP and the proposed Bemboka NP, May 1992 (unpub.)

This includes records from R. Outhred's survey of 215 sites in Wadbilliga National Park in 1984, from D. Keith's survey of 13 sites and 21 sites surveyed by I. Crawford (et al.) in 1992 in Wadbilliga and the proposed Bemboka Nation al Park. List of about 500 native and exotic species.

1:250 000 topographic map: Bega

LGA: Bega Valley

495 DODSON, J.R., KODELA,P.G. & MYERS, C.A.(1988)

Vegetation survey of the Tantawanglo research catchments in the Eden Forestry Region, New South Wales

Forest Resources Series No 4, (Forestry Commission of NSW: Sydney)

Includes abundance data for species from 30 permanent plots (radius 20 m) in Glenbog State Forest including cover and basal area together with list of vascular species for the research catchments.

1:250 000 topographic maps: Bega

LGA: Bega Valley

496 FANNING, F.D. & FATCHEN, T.J. (1990)

The Upper Wog Wog River catchment of Coolangubra and Nalbaugh State Forest (Mines Road area) New South Wales; a flora and fauna survey

Forest Resources Series No 12 (Forestry Commission of NSW: Sydney)

Detailed description of vegetation recognising 14 types with with list of 287 plant species including frequecy over 113 sites.

1:250 000 topographic maps: Bega

LGA: Bega Valley

497 FANNING, F.D. & MILLS, K. (1990)

Flora and fauna survey of the Myanba Creek catchment, Coolangubra State Forest, Eden Region

Forest Resources Series No 11 (Forestry Commission of NSW: Sydney)

Detailed description of vegetation recognising 19 types with list of 338 plant species including frequecy over 107 sites.

1:250 000 topographic maps: Bega

LGA: Bega Valley

498 FANNING, F.D. & MILLS, K. (1991)

The Stockyard Creek catchment of Coolangubra State Forest, New South Wales; a flora and fauna survey

Forest Resources Series No 13 (Forestry Commission of NSW: Sydney)

Detailed description of vegetation recognising 25 types with list of 280 plant species including frequecy over 66 sites.

1:250 000 topographic maps: Bega

LGA: Bega Valley

499 KEITH, D.A. (1990)

Rare and biogeographically significant vascular plant species of the Eden Region, South-eastern New South Wales: a listing for the "fine-filter " approach.

Proceedings of the Linnean Society of N.S.W. 112: 111–132.

Lists 13 species endemic to the region, 40 rare or threatened in an Australia-wide context, 34 uncommon throughout their distribution, 6 resticted outsidet the Eden region, 279 uncommon within the region but common elsewhere, 8 depleted in the wild, 183 reaching their geographical limit of distribution in the Eden region, 23 represented in the Eden region by geographically distinct pop ulations, and 8 represented by ecologically disjunct populations. Locations and selection criteria included as well as a map of the area.

1:250 000 topographic map: Bega

LGA: Bega Valley, Cooma–Monaro, Bombala

500 KEITH, D. & ASHBY, E. (1992)

Vascular plants of conservation significance in the South East Forests of New South Wales

NSW National Parks & Wildlife Service Occasional Paper No 11

Lists vascular plant taxa of conservation significance in the South East Forest region extending east of Bombala from Bermagui to the Victorian border along the coast. 432 taxa are listed under various categories of rarity, biogeographic or ecological significance. Appendices contain a full account of distributional data gathered on each taxon from herbaria, vegetation survey literature and databases, taxonomic literature and botanists.

1:250 000 topographic map: Bega, Mallacoota

LGA: Bega Valley, Bombala

501 PAYNE, R. (1988)

Vegetation assessment for the proposed U.H.F. transmission station on Little Forest Plateau, Morton National Park

(unpub.)

Includes list of 220 plants from Little Forest Plateau. Map and photographs of communities included. Location of species in Woodland/Forest, Heathland/Sedgeland or Closed Forest is noted. 16 km south of Ulladulla

1:250 000 topographic map: Ulladulla

LGA: Shoalhaven

NORTHERN TABLELANDS

502 BENSON, J. (1992)

The distribution, abundance and conservation status of *Grevillea beadleana* (Proteaceae): an endangered species

Cunninghamia 2(4): 503–521

Includes a list of 130 species found in association with *G. beadleana* in Guy Fawkes National Park and at Binghi.

1:250 000 topographic map: Grafton, Dorrigo

LGA: Walcha, Dumaresq, Severn, Tenterfield, Nymboida

503 CURTIS, D. (1992)

Native trees and shrubs of the Northern Tablelands: the Armidale area, Dangarsleigh area, Uralla area and Wongwibinda area.(separate leaflets)

Greening Australia: Armidale

Lists of trees and shrubs for local regions with species listed by topographical position and underlying geology.

1:250 000 topographic map: Dorrigo, Manilla

LGA: Armidale, Dumaresq, Uralla

504 CURTIS, D., DAVIES, D., & LIND, J. (1992)

Native trees and shrubs of the Northern Tablelands of N.S.W. The Invergowrie area

Greening Australia Field Notes (Greening Australia: Armidale)

A list of trees and shrubs for 15 sites in the Armidale region with a listing of species associated by topographical position and underlying geology.

1:250 000 topographic map: Dorrigo

LGA: Dumaresq

505 CURTIS, D. & ROBINSON, G. (1992)

Native trees and shrubs of the Northern Tablelands: the Glen Innes area

Greening Australia: Armidale

Lists of trees and shrubs with species listed by topographical position and underlying geology.

1:250 000 topographic map: Grafton

LGA: Glen Innes

506 HOSKING, J. (1990)

Flora of Werrikimbe National Park

(unpub.)

A list of 430 species with common names. Includes introduced species. 66 km east of Walcha.

1:250 000 topographic map: Hastings

LGA: Walcha

507 ROBINSON, G.G. (about 1990)

A guide to eucalypts in the Glen Innes area

Glen Innes Natural Resource Advisory Committee

Describes over 30 common eucalypts of the area with information on their distribution and potential uses.

1:250 000 topographic map: Grafton

LGA: Glen Innes

508 ROGERS, R.W. & WHALLEY, R.D.B. (1989)

Relationship between diaspore characteristics and distribution of grasses around sheep camps on the Northern Tablelands of New South Wales

Australian Journal of Botany 37: 501–510

Twenty-seven species of grasses are listed according to association with sheep camps. Attributes described include length/breadth ratio for caryopsis, germination, life history and origin.

1:250 000 topographic map: Dorrigo

LGA: Dumaresq

CENTRAL TABLELANDS

509 BOWDEN, I. (1962)
Orchids of the Blue Mountains NSW
Australian Naturalist 12(3): 11–20
Orchids of the sandstone regions including the catchment of the Grose River and south to the Coxs River.
1:250 000 topographic map: Sydney
LGA: Blue Mountains

510 DOWNING, A.J., RAMSAY, H.P., & SCHOFIELD, W.B. (1991)
Bryophytes in the vicinity of Jenolan Caves, New South Wales
Cunninghamia 2(3): 371–384
Records 115 bryophytes including five new records of mosses for NSW and 18 additions to the mosses of the Central Tablelands.
1:250 000 topographic map: Sydney
LGA: Blue Mountains

511 FORD, A.J. (1990)
Flora list of Clandulla State Forest
(unpub.)
A one day survey listing 125 species by families. Locality map. Near Kandos.
1:250 000 topographic map: Singleton
LGA: Rylstone

512 GOODE, J. (1989)
Study of plant succession in the Blue Mountains
Student exercise (unpub.)
Transect through sedge swamp, sheltered gully and open-forest at Bullaburra near Minnatonka Falls describing vegetation and listing about 100 species.
1:250 000 topographic map: Sydney
LGA: Blue Mountains

513 HOLLAND, W.N. BENSON, D.H. & McRAE R.H.D. (1992)
Spatial and temporal variation in a perched headwater valley in the Blue Mountains: geology, geomorphology, vegetation, soils and hydrology
Proceedings of the Linnean Society of N.S.W. 113: 271–295.
Includes list of 100 species for perennial swamp, ephemeral swamp and wood land on sandstone near Leura.
1:250 000 topographic map: Sydney
LGA: Blue Mountains

514 INGRAM, C.K. (1987)

Checklist of the vascular flora of Mount Tomah

The Mount Tomah Book. (The Mount Tomah Society and the Royal Botanic Gardens, Sydney): 63–85

A checklist of 650 species (ferns, cycads and conifers, monocots and dicots). Also a checklist of reported occurrences in the area which includes 42 species. An historical account of the area with chapters on vegetation, insects, birds, fauna, geography and geology of the area.

1:250 000 topographic map: Sydney

LGA: Blue Mountains

515 KODELA, P.G. (1989)

Vascular plant species list for Robertson Nature Reserve, Central Tablelands, NSW

(unpub.)

List of 60 species including introduced species.

1:250 000 topographic map: Wollongong

LGA: Wingecarribee

516 KODELA, P.G. (1990a)

Robertson Plateau rainforest: remnants of the Yarrawa Brush

National Parks Journal 34(4): 28–31.

Includes list of 100 species found in patches of Robertson rainforest. Listed by the headings of mosses, ferns, herbs, treesand shrubs and climbers. Map of present and former extent of Yarrawa Brush.

1:250 000 topographic map: Wollongong

LGA: Wingecarribee

517 KODELA, P.J. (1990b)

Modern pollen rain from forest communities on the Robertson Plateau, New South Wales

Australian Journal of Botany 38: 1–24

Rainforest, open to tall open-forest with mesic understorey, tall open-forest with predominantly sclerophyllous understorey and dry open to tall open-forest sites with minimal disturbance were sampled. The checklist of 200 species lists the percentage basal cover for arboreal species, and percentage foliage cover for other taxa.

1:250 000 topographic map: Wollongong

LGA: Wingecaribee

518 KODELA, P.G. (1992a)

Native vegetation remnants and notes on some rare and locally significant plant species in the Robertson area New South Wales.

Eucryphia (Journal of the Robertson Environment Protection Society Inc) 6: 6–9

Discusses the importance of vegetation remnants in the area with details of the rare species *Eucalyptus macarthurii, Eucryphia moorei, Gentiana wingecarribiensis, Lilaeopsis polyantha* and *Livistona australis*

1:250 000 topographic map: Wollongong

LGA: Wingecarribee

519 KODELA, P.G, (1992b)

Plant species recorded from pastures, roadsides and wasteland areas in the Robertson, Moss Vale region, Central Tablelands.

(unpub.)

Lists by family 130 native and exotic species.

1:250 000 topograpic map: Wollongong

LGA: Wingecarribee

520 KODELA, P.G. & HOPE, G.S (1992)

Wingecarribee Swamp: Statement of Significance

National Trust of Australia (New South Wales)

120 species are listed from this large montane peatland. The swamp contains the rare herb *Gentiana wingecarribiensis* and the rare orchid *Prasophyllum uroglossum*, both endemic to the site.

1:250 000 topographic map: Wollongong

LGA: Wingecarribee

521 KODELA, P.G., JAMES, T.A., COVENY, R.G., & HIND, P.D. (1992)

Reconnaissance survey of the vegetation at Long Swamp, near Penrose, Central Tablelands, N.S.W.

Royal Botanic Gardens Sydney (unpub.)

Includes list of 35 species recorded from Long Swamp from July–September, 1992. Another 33 species are recorded near the swamp margins and surrounding slopes and includes the rare and uncommon plants: *Eucalyptus macarthurii, Phyllota humifusa*, and the fern *Botrychium australe*.

1:250 000 topographic map: Wollongong

LGA: Wingecarribee

522 PORTER, C.L. (1992)

Distribution and abundance of *Blandfordia cunninghamii* Lindley (Blandfordiaceae)

Cunninghamia 2(4): 523–532

Includes list of 70 species found in association with *Blandfordia* in the Blue Mountains.

1:250 000 topographic map: Sydney

LGA: Blue Mountains

523 PRATTEN, C. (1986)

A case for a further Flora Reserve within Mullions Range State Forest No 176.

(unpub.)

The distribution and/or occurrence of *Eucalyptus radiata ssp. robertsonii, E. sparsifolia* and *Acacia boormanii* in the Mullions Range State Forest are discussed and a new Flora Reserve is recommended. An alphabetically arranged list of 139 plants growing in the Bosches Creek Flora Reserve and the study area is appended. Main text without species list published in *National Parks Journal* 30(6): 19–21.

1:250 000 topographic sheet: Bathurst

LGA: Cabonne

524 RAMSAY, H.P., DOWNING, A. & SCHOFIELD, W.B. (1990)

Bryophytes of Mount Tomah Botanic Garden

Cunninghamia 2(2): 295–303

A preliminary listing of 85 bryophytes found in the gardens and the rainforest area.

1:250 000 topographic map: Sydney

LGA: Blue Mountains

525 ROBERTSON ENVIRONMENT PROTECTION SOCIETY (1993)

A guide to the Yarrawa Brush: trees, shrubs and vines of the Robertson rainforest remnants

The Robertson Environment Protection Society Inc.

Describes over 50 species found in patches of Robertson rainforest with map of rainforest remnants.

1:250 000 topographic map: Wollongong

LGA: Wingecarribee

526 STILES, A. (1991)

Checklist of vascular plants in Robertson rainforests

Eucryphia (Journal of the Robertson Environment Protection Society Inc) No.2, March.

List of 140 native species with common names.

1:250 000 topographic map: Wollongong

LGA: Wingecarribee

SOUTHERN TABLELANDS

527 ALBRECHT, D. (1987)

Preliminary checklist of the vascular plants of Nalbaugh National Park

Royal Botanic Gardens, Melbourne (unpub.)

Checklist of 382 species listed including introduced species.

Nalbaugh National Park is 26 km SE of Bombala.

1:250 000 topographic map: Bega

LGA: Bombala

528 BENSON, J.S. & WYSE JACKSON, M. (1993)

The native grasslands of the Monaro Region.

In McDougall, K. & Kirkpatrick, J.B. *Conservation of lowland native grasslands in south-eastern Australia* (Worldwide Fund for Nature: Sydney)

Survey of native grassland remnants between Canberra and Bombala including floristic lists, vegetation classification and key sites for conservation.

1:250 000 topographic map: Canberra, Bega

LGA: Queanbeyan, Cooma-Monaro, Snowy River, A.C.T.

529 CRAWFORD, I. (1988)

Bombala River plant collection

(unpub.)

An alphabetical listing by family of 200 species found within 1.1 km northwest of the confluence of the Bombala River and Back Creek. Description of the area with dominant tree species given. Vascular plants, lichens, liverworts & mosses included.

1:250 000 topographic map: Bega

LGA: Bombala

530 KODELA, P.G. & FOSTER, D.A. (1990)

Common plants and soil salinity in the Lower Boro area, Southern Tablelands, NSW

Cunninghamia 2(2): 217–222.

A list of 135 plant species that are found in the area. A habitat information coding is used to designate locations of the species.

1:250 000 topographic map: Canberra

LGA: Mulwaree

531 LEIGH, J.H., WIMBUSH, D.J., WOOD, D.H., HOLGATE, M.D., SLEE, A.V., STANGER, M.G., & FORRESTER, R.I. (1987)

Effects of rabbit grazing and fire on a subalpine environment

Australian Journal of Botany 35: 433–464

Contains a list of 188 species of vascular plants and one species of moss from the study site near Kiandra. Species are listed by life form. Individual species are described as is an historical perspective of the vegetation.

1:250 000 topographic map: Wagga Wagga

LGA: Snowy River

532 THOMAS, D. (1992)

Millended Springs vegetation survey

Water Board Catchment Services Unit: Sydney

Located 45 km south of Goulburn on the western side of the Tarago – Lower Boro Road, the survey includes a list of 125 species observed at ten sites. Map included.

1:250 000 topographic map: Canberra

LGA: Goulburn

533 WHAITE, J. & O'NEILL, M. (1987)
An outline of the flora of the Goulburn district
Society for Growing Australian Plants, Canberra region Newsletter 7(6): 7–10.
Lists 400 species in alphabetical order by genus. Areas around Bungonia Gorge, Shoalhaven Gorge and Lake Bathurst described.
1:250 000 topographic map: Goulburn
LGA: Mulwaree

NORTH WESTERN SLOPES

534 BENSON, J. & ANDREW, D. (1990)
The flora, fauna and conservation significance of Ben Halls Gap State Forest, Nundle, NSW
Technical Report No. 90/1 (NSW National Parks & Wildlife Service)
An alphabetical list of 120 species by growth form and presence in plant associations in the area. Some bryophytes are included. Plant species of special significance discussed.
1:250 000 topographic map: Tamworth
LGA: Nundle

535 HOSKING, J. (1990a)
Flowering times of plants found in Oxley Park, Tamworth
Cunninghamia 2(2): 197–216
List of 434 plants and their flowering times. Addendum in *Cunninghamia* 2(3): 501.
1:250 000 topographic map: Tamworth
LGA: Parry

536 HOSKING, J. (1990b)
Flora of Warrabah National Park
(unpub.)
List of 400 species with common names including introduced species. 35 km N.E. of Manilla
1:250 000 topographic map: Manilla
LGA: Manilla

537 HOSKING, J. (1990c)
Flora of Attunga State Forest
(unpub.)
List of 313 species with authorities, common names and introduced species. Tamworth area.
1:250 000 topographic map: Manilla
LGA: Parry

538 INOUYE, D.W. & PYKE, G.H. (1988)

Pollination biology in the Snowy Mountains of Australia: comparisons with montane Colorado, USA

Australian Journal of Ecology 13(2): 191–210

Aspects of pollination biology were examined in the Charlottes Pass area from Dec. 1983 – Mar. 1984 which included flowering phenology, corolla tube lengths, flower colour, ultraviolet reflectance patterns, visitation rates to the flowers and proboscis lengths of the flower-visiting insects. Forty-three species are listed with observation periods, visitation rates and flower visitors. Appendix contains 62 species with corolla length, flower colour, UV reflection and length of flowering period.

1:250 000 topographic map: Tallangatta

LGA: Snowy River

CENTRAL WESTERN SLOPES

539 TURNER, R.J. (1973)

Native plants from Kangarooby

Forestry Office, Forbes (unpub.)

A checklist of 137 species, with common names, found in the Kangarooby district (33°43′00"S 148°20' 00"E).

1:250 000 topographic map: Forbes

LGA: Weddin

540 ALTHOFER, G.W. & HARDEN, G.J. (1980)

The flora of Mt Arthur Reserve, Wellington, NSW.

Trustees of Mt Arthur Reserve: Wellington

A checklist of 530 species including bryophytes and lichens. Includes distribution and habitat. Location map.

1:250 000 topographic map: Dubbo

LGA: Wellington

541 LEPSCHI, B.J. (1989)

Preliminary floristic list for Cowal State & National Forest N.S.W.

(unpub.)

List of 75 species including exotic species.

1:250 000 topographic map: Narromine

LGA: Narromine

542 TURNER, R.J. (1973)

Species list for Bumberry State Forest No. 891

Forestry Office, Forbes (unpub.)

List of 123 species. Located east of Parkes.

1:250 000 topographic map: Forbes
LGA: Parkes

See also SWS - Norris & Thomas (1991)

SOUTH WESTERN SLOPES

543 BURROWS, G.(1992a)
The Rock Nature Reserve: species list
Charles Sturt University – Riverina (unpub.)
List of about 220 species, both native and exotic, incorporating lists by J.H. Willis (1967–69), Willis, Johnston and Fleetwood (NSW National Parks & Wild life Service), and G.Burrows (1987–90). Located 30 km southwest of Wagga.
1:250 000 topographic map: Wagga Wagga
LGA: Lockhart

544 BURROWS, G.(1992b)
Pomingalarna Reserve: species list
Charles Sturt University – Riverina (unpub.)
List of about 200 species, both native and exotic, incorporating lists by J. Webb and G.Burrows. Located 5 km west of Wagga.
1:250 000 topographic map: Wagga Wagga
LGA: Wagga Wagga

545 BURROWS, G.(1992c)
Plant species list for the Winery Hill — an area of remnant vegetation on the campus of Charles Sturt University – Riverina
Charles Sturt University – Riverina (unpub.)
List of 111 species, 50 native and 61 exotic. Located 5 km north of Wagga.
1:250 000 topographic map: Wagga Wagga
LGA: Wagga Wagga

546 BURROWS, G. (no date)
Flora of Mt Galore
Charles Sturt University – Riverina (unpub.)
List of about 100 species, both native and exotic, incorporating lists by J.H. Willis (1967) and J. Bladen et al (1990). Located 14 km north of Lockhart.
1:250 000 topographic map: Jerilderie
LGA: Lockhart

546 BURROWS, G. & LEVETT, G. (1991)
Plant species list for Bethungra Reserve (a N.S.W. State Recreation Area)
Charles Sturt University – Riverina (unpub.)

List of about 80 native species (excluding grasses) for area 4 km east of Bethungra

1:250 000 topographic map: Cootamundra

LGA: Junee

547 NORRIS, E.H. & THOMAS, J. (1991)

Vegetation on rocky outcrops and ranges in central and south-western New South Wales

Cunninghamia 2(3): 411–441

Lists 340 species (55 exotic) from 19 sites on sandstone, granite, slate or rhyolite geology. Discussion of significant species, vegetation and conservation and management issues. Covers an area from Roto to Corowa including parts of the Central Western Slopes, South Western Slopes and South Western Plains subdivisions.

1:250 000 topographic maps: Ivanhoe, Manara, Narrandera, Cargelligo, Jerilderie, Booligal

LGA: Central Darling, Carrathool, Murrumbidgee, Griffith, Leeton, Urana, Corowa, Narrandera, Lockhart

548 WHITING, E. (1988)

Plant list for Bunganbil State Forest

Part of a report submitted to NSW National Parks & Wildlife Service (unpub.)

113 species arranged alphabetically by family. Common names and introduced species included. Located 39 km north of Narrandera.

1:250 000 topographic map: Narrandera

LGA: Narrandera

549 WHITING, E. (1988)

Plant list for Lake Talbot Reserve, Narrandera

Forms part of report to NSW National Parks & Wildlife Service (unpub.)

Eighty-one species arranged alphabetically by family. Common names and in troduced species included.

1:250 000 topographic map: Narrandera

LGA: Narrandera

550 WHITING, E. (1988)

Plant list for Moombooldool – Kamarah roadside

Part of a report submitted to NSW National Parks and Wildlife Service (unpub.)

Ninety species listed alphabetically by family. Common names and introduced species included. Kamarah is 13 km west of Ardlethan on the Griffith Road.

1:250 000 topographic map: Narrandera

LGA: Narrandera

551 WHITING, E. (1988)

Plant list for the reserve north of Kamarah

Part of a report submitted to the NSW National Parks and Wildlife Service (unpub.)

150 species listed alphabetically by family. Common names and introduced species included. Kamarah is 13 km west of Ardlethan on the Griffith Road.

1:250 000 topographic map: Narrandera

LGA: Narrandera

552 WHITING, E. (1988)

Species additional to the published list for The Rock Nature Reserve

(unpub.)

17 species listed additional to list held by the National Parks & Wildlife Service, Griffith.

1:250 000 topographic map: Wagga Wagga

LGA: Lockhart

553 WHITING, E. (1991–1992)

Species Lists for the Northern Riverina

(unpub.)

Species lists of areas within a 150km radius of Leeton in the Northern Riverina (includes some of above references). State Forests included: MIA Forests 2 & 3, Binya State Forest, Boona State Forest, Kulki State Forest, Kockibitoo State Forest, Livingstone State Forest, Jurambula State Forest, Kolkilbertoo State Forest, Mejum State Forest, Ardlethan State Forest, Beckom State Forest, Bunganbil State Forest, Billenbah State Forest, Gillenbah State Forest, Buckingbong State Forest, Berry Jerry State Forest. Other areas include roadsides and Mt. Galore, Lake Cargelligo Weir and floodplain and Yanco Weir.

Pertinent also to the South Western Plains and the Central Western Slopes.

1:250 000 topographic map: Narrandera

LGA: Leeton, Narrandera

See also Margules & partners, P & J Smith ecological consultants, Department of Conservation Forests and Lands Victoria (1990)

NORTH WESTERN PLAINS

554 WADE, T. (1992)

The Brigalow outlier: a resource inventory of the brigalow vegetation communities west of the Culgoa River

Department of Conservation and Land Management

A detailed study of an area north of Bourke, including vegetation descriptions and floristic lists, and suggesting that this vegetation is floristically distinct from brigalow communities elsewhere.

1:250 000 topographic map: Enngonia

LGA: Bourke, Brewarrina

See also NFWP – Pressey, Conn & Porter (1990)

SOUTH WESTERN PLAINS

555 BRICKHILL, J. (1985-1988)

Plant list, Willandra National Park

(unpub.)

List of 100 native and introduced species with common names and comments on distribution.

1:250 000 topographic map: Booligal

LGA: Carrathool

556 McINTYRE, S., LADIGES, P.Y. & ADAMS, G. (1988)

Plant species-richness and invasion by exotics in relation to disturbance of wetland communities on the Riverine Plain, N.S.W.

Australian Journal of Ecology 13(4): 361–373

Three habitats are examined in the irrigation districts which were subjected to varying intensities of human-induced disturbance. They were: swamps, road side table-drains, and rice crops. An appendix contains a species list of 125 macrophytic plants including seed bank records. Exotics included.

1:250 000 topographic maps: Narrandera, Deniliquin, Jerilderie

LGA: Carrathool, Murrumbidgee, Jerilderie, Wakool, Murray, Conargo

557 PICKARD, J. (1974)

Floristic lists from around gypsum mines near Ivanhoe

Royal Botanic Gardens, Sydney (unpub.)

A checklist of 66 species found around 5 gypsum mines (Marlow, A.P.I., Manara, Beilpajah, and un-named) in the Ivanhoe area.

1:250 000 topographic map: Ivanhoe

LGA: Central Darling

558 PORTENERS, M.F. (1993)

The natural vegetation of the Hay, Deniliquin and Booligal 1:250 000 maps sheets

Cunninghamia 3(1): 1–122

Species list of 800 native and naturalised plants. Sixteen vegetation communities. Vegetation maps at 1:250 000 scale.

1:250 000 topographic maps: Hay, Deniliquin, Booligal

LGA: Carathool, Hay, Balranald, Murrumbidgee, Windouran, Conargo, Wakool, Murray, Central Darling

559 PRESSEY, R.L., BELL, F.C., BARKER, J., RUNDLE, A.S., BELCHER, C.A. (1984)

Bio-physical features of the Lachlan–Murrumbidgee confluence, South-Western New South Wales

NSW National Parks and Wildlife Service (unpub.)

Discusses the hydrology, geomorphology, soils, vegetation, fauna, alteration to the environment, and management of the area with recommendations. Appended species list contains 300 plant species found in this survey or from other sources. Also includes an appended list of new plant records for the botanical region and their recording sites. Maps included.

1:250 000 topographic maps: Balranald, Hay

LGA: Balranald, Hay, Wakool

560 SEMPLE, W.S. (1986)

The Finley Arboretum site: A brief description, including a list of vascular plants

Western Region Technical Bulletin No.26 (Soil Conservation Service of NSW)

Notes on soils and vegetation. Ninety-six species recorded from the site (about 5 km south of Finley), 1984–1986, arranged alphabetically by family with common names. Photographs of the arboretum included.

1:250 000 topographic map: Jerilderie

LGA: Berrigan

See also NFWP – Pressey, Conn & Porter (1990); SWS – Norris & Thomas (1991); SFWP – Scott (1992); NSW general – Margules & partners, P & J Smith ecological consultants, Department of Conservation Forests and Lands Victoria (1990)

NORTH FAR WESTERN PLAINS

561 DUNCAN, A. AND COVENY, R.G. (1988)

Sturt National Park floristic list

(unpub.)

This listing of 420 species was compiled from species lists prepared by Bob Coveny, the Anzses Botany Group: Barbara Wiecek, Elizabeth Brown, Tony Rodd and Jan Reilly.

1: 250 000 topographic map: Milparinka

LGA: unincorporated area

562 PRESSEY, R.L., CONN, J.S. & PORTER, J.L. (1990)

Vascular plants with restricted distributions in the Western Division of NSW

Proceedings of the Linnean Society of N.S.W. 112: 213–227

A systematic listing of 209 plant species. Categories and Priorities as defined in text are given as are rare or threatened and presumed extinct plants.

1:250 000 topographic maps: Ana Branch, Ponncarie, Balranald, Booligal, Menindee, Manara, Ivanhoe, Nymagee, Broken Hill, Wilcannia, Barnato, Cobar, Cobham Lake, White Cliffs, Louth, Bourke, Walgett, Milparinka, Urisino, Yantabulla, Enngonia, Angledool

LGA: Wentworth, Balranald, Central Darling, Carrathool, Cobar, Bourke, Walgett, Brewarina

SOUTH FAR WESTERN PLAINS

563 FOX, M.D. (1991)

The natural vegetation of the Ana Branch – Mildura 1:250 000 map sheet (New South Wales)

Cunninghamia 2(3): 443–493

This paper includes a detailed vegetation map together with a list of 300 species with 33 exotic species in 15 vegetation communities. There are several significant plant communities in the area with seven rare or endangered species. Only 1% of the region is in a formal conservation reserve.

1:250 000 topographic maps: Ana Branch, Mildura

LGA: Wentworth, Unincorporated area

564 NOBLE, J.C. (1989)

Fire studies in mallee *(Eucalyptus* spp.) communities of western New South Wales: the effects of fires applied in different seasons on herbage productivity and their implications for management.

Australian Journal of Ecology 14(2): 169–187

The post-fire development of herbaceous understories of *Triodia*/mallee burnt in different seasons was studied over a 3 year period. An appended species list contains 67 species and their presence or absence in 1978–81 and 1984.

1:250 000 topographic map: Ponncarie

LGA: Wentworth

565 SCOTT, J.A. (1992)

The natural vegetation of the Balranald–Swan Hill area

Cunninghamia 2(4): 597–652

This paper includes a detailed vegetation map together with a list of about 500 species including exotic species. Twenty vegetation communities are described and vegetation distribution, species composition, landuse and changes to native vegetation, and conservation of vegetation are discussed.

1:250 000 topographic map: Balranald, Swan Hill

LGA: Wentworth, Balranald, Wakool, Hay

See also NFWP – Pressey, Conn & Porter (1990)

NEW SOUTH WALES GENERAL

566 ADAM, P., WILSON, N.C., & HUNTLEY, B. (1988)

The phytosociology of coastal saltmarsh vegetation in New South Wales.

Wetlands (Australia) 7(2): 35–85

Lists 217 taxa in twenty-five saltmarsh communities. Most communities are species poor, with a small number of dominant species.

1:250 000 topographic map: Bega, Mallacoota, Ulladulla, Wollongong, Sydney, Newcastle

LGA: Great Lakes, Port Stephens, Newcastle, Lake Macquarie, Wyong, Gosford, Wollongong, Wingecarribee, Eurobodalla, Bega Valley, Sutherland, Randwick, Waverly, Woollahra, Manly, Warringah

567 ADAM, P., STRICKER, P., WIECEK, B.M. & ANDERSON, D.J. (1989)

The vegetation of seacliffs and headlands in New South Wales, Australia

Australian Journal of Ecology 14(4): 515–547

A phytosociological survey of seacliff and headland vegetation from Forster to the Victorian border. Analysis of the data led to the recognition of 15 plant communities. Includes 328 species native and introduced.

1:250 000 topographic map: Bega, Mallacoota, Ulladulla, Wollongong, Sydney, Newcastle

LGA: Great Lakes, Port Stephens, Newcastle, Lake Macquarie, Wyong, Gosford, Wollongong, Wingecarribee, Eurobodalla, Bega Valley, Sutherland, Randwick, Waverley, Woollahra, Manly, Warringah

568 CAROLIN, R. & CLARKE, P. (1991)

Beach plants of south-eastern Australia

Sainty & Associates: Sydney

Descriptions and photographs of about 180 coastal plants with notes on habitat and ecology. Based on Clarke, P.J. (1989a,b).

1:250 000 topographic maps: Bega, Ulladulla, Wollongong, Sydney, Newcastle, Hastings, Coffs Harbour, Maclean, Tweed Heads

LGA: Bega Valley, Eurobodalla, Wingecarribee, Wyong, Port Stephens, Great Lakes, Kempsey, Nambucca, Belligen, Ulmarra, Maclean, Richmond River, Ballina, Byron, Tweed, Sutherland, Randwick, Waverley, Woollahra, Manly, Warringah

569 CLARKE, P.J. (1989a)

Coastal dune vegetation of New South Wales

Technical Report No.89/1University of Sydney, Coastal Studies Unit, and Technical Report No.21, Soil Conservation Service of NSW.

The structure and floristic composition of the Holocene sand dunes of NSW are described. Species are described from 247 sites. Contains an annotated bibliography on the vegetation of coastal sand dunes of NSW: 45 reviewed references with headings of: study location, physical environment, methods, general vegetation, sand dune vegetation, species list, management and references.

1:250 000 topographic maps: Bega, Ulladulla, Wollongong, Sydney, Newcastle, Hastings, Coffs Harbour, Maclean, Tweed Heads

LGA: Bega Valley, Eurobodalla, Wingecarribee, Wyong, Port Stephens, Great Lakes, Kempsey, Nambucca, Belligen, Ulmarra, Maclean, Richmond River, Ballina, Byron, Tweed, Sutherland, Randwick, Waverley, Woollahra, Manly, Warringah

570 CLARKE, P.J. (1989b)

Coastal dune plants of New South Wales

Technical Report No.89/4 University of Sydney, Coastal Studies Unit, and Technical Report No.22, Soil Conservation Service of NSW.

Part of a study on coastal sand dune management. Includes 386 species with individual plant identification, morphology, life history, physiology, climate, soil, regeneration, useful properties, distribution, and habitat. The species list includes common name, life form, habitat and distribution and introducted species are included.

1:250 000 topographic maps: Bega, Ulladulla, Wollongong, Sydney, Newcastle, Hastings, Coffs Harbour, Maclean, Tweed Heads

LGA: Bega Valley, Eurobodalla, Wingecarribee, Wyong, Port Stephens, Great Lakes, Kempsey, Nambucca, Belligen, Ulmarra, Maclean, Richmond River, Ballina, Byron, Tweed, Sutherland, Randwick, Waverley, Woollahra, Manly, Warringah.

571 CLARKE, P.J. & CHAPMAN, D.M. (1989)

Coastal Dune Database

Technical Report No.89/2 University of Sydney, Coastal Studies Unit

The database DUNESVY is used to document the coastal sand dune environments of NSW, their site characteristics and plant species. Part of joint research project on the coastal dunes of NSW and their management undertaken by the University of Sydney Coastal Studies Unit and the Soil Conservation Service of NSW.

See Clarke, P.J. (1989a,b) above

572 MARGULES & PARTNERS, P & J SMITH ECOLOGICAL CONSULTANTS, DEPARTMENT OF CONSERVATION FORESTS AND LANDS VICTORIA (1990)

River Murray riparian vegetation study

Murray–Darling Basin Commission

The study area includes the floodplain of the Murray River and its anabranches, and includes the Edward–Wakool system, from below Hume Dam to the upper end of Lake Alexandrina.

Data collected were the species present, their relative abundance, the condition of the eucalypts, the amount of eucalypt regeneration and indices of grazing pressure. Thirty-seven plant communities were identified. Structural vegetation map included. Species list includes 660 species by community and river section. Sixty-eight threatened species listed.

1:250 000 topographic map: Mildura, Balranald, Swan Hill, Deniliquin, Jerilderie, Bendigo, Wangaratta

LGA: Wentworth, Balranald, Wakool, Murray, Berrigan, Corowa, Hume, Holbrook, Tumbarumba

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Bryophytes of the Royal Botanic Gardens, Government House and the Domain, Sydney

H.P. Ramsay, R.G. Coveny, E.A. Brown and A.K. Brooks

Abstract

H.P. Ramsay, R.G. Coveny, E.A. Brown & A.K. Brooks. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney NSW, Australia 2000), 1993. Bryophytes of the Royal Botanic Gardens, Government House and the Domain, Sydney. Cunninghamia *3(1): 215–229.* More than 90 species of bryophytes (70 mosses, 24 hepatics and one anthocerote) have been collected in the Royal Botanic Gardens, Government House and the surrounding Domain, an area of 30 hectares, Sydney. Species present include some new records for New South Wales and one for Australia and include representatives of up to 25 families of mosses and 13 families of hepatics.

Introduction

The Royal Botanic Gardens, Sydney lies on the foreshores of Port Jackson (Sydney Harbour) at Farm Cove (Fig. 1). Although bryophytes have been studied at the National Herbarium of New South Wales, in the Royal Botanic Gardens, Sydney since the late nineteenth century, few specimens are annotated as having been collected there and no species list has been published for the Royal Botanic Gardens, Government House or the Domain. The site occupied by the Royal Botanic Gardens has been cultivated for agriculture and horticulture since the earliest days of European settlement which began in Australia on this site, in January 1788 (Gilbert 1986).

Watercolours of adjacent Sydney Cove by William Bradley in 1788 (Bradley 1786–1792) show relatively dense stands of trees above a rocky foreshore, but with grassy understorey, behind the shoreline. The original vegetation behind the mudflats consisted of eucalypt woodland, 'brushwood' and a variety of smaller plants, occurring on exposed rocky outcrops and in the more sheltered fern gullies of the creek beds, while near the salt water the vegetation included Swamp Oak, *Casuarina glauca*, Port Jackson Fig, *Ficus rubiginosa*, and teatrees. Several species of eucalypt as well as Turpentine, *Syncarpia glomulifera* and Smooth-Barked Angophora, *Angophora costata* were present (Wilson 1986).

The underlying bedrock is sandstone and soils are sandy and shallow with some rocky outcrops. Reclamation of low lying land on the foreshores of the Harbour and building of the sea wall enabled the area of land available for cultivation and recreation to be increased from the original small farm area. Soils have since been modified by supplementation with other soils, fertilisers and mulching.

At present the Royal Botanic Gardens and Domain occupy an area of 30 hectares with the Domain parkland acting as an insulator from the Central Business District and its high-rise buildings (Johnson in Wilson 1986). By 1986 all that remained of the original vegetation were some gnarled trees of *Angophora costata, Ficus rubiginosa, Casuarina glauca* and a few specimens of *Eucalyptus pilularis, E. tereticornis, E. resinifera, Glochidion ferdinandi* and *Rapanaea variabilis* that are clearly descended from ones that were on the site (Wilson 1986, L.A.S. Johnson pers. comm.).

History of bryophyte collections and bryology at the National Herbarium of New South Wales (NSW)

Attached to and forming an integral part of the Royal Botanic Gardens complex are the administrative, research and educational services. The Brown Building houses the National Herbarium of New South Wales, referred to by its acronym NSW. Among the large array of plant specimens held is an extensive collection of Australian bryophytes, one of the largest in Australia (Ramsay & Seur 1990).

The earliest bryophyte specimens collected in New South Wales and held in the National Herbarium date back to the 1880's. Three prominent figures, Thomas Whitelegge, William Forsyth and William Walter Watts, whose specimens form the basis of the Australian collections at NSW, contributed significantly to knowledge of bryophytes in Australia, particularly New South Wales.

Thomas Whitelegge (1850–1927)

Thomas Whitelegge (1850–1927), born in Stockport, Cheshire, England, arrived in Sydney in early 1883 and was appointed to the Australian Museum, being in charge of Invertebrates from 1883–1908 (Obituary 1927). He also had an interest in ferns and mosses and in 1884 began to gather information on the mosses of New South Wales primarily in Sydney, Gosford, Moss Vale and Blue Mountains. At the urgent request of Dr. V.F. Brotherus in Helsinki, who was preparing the volumes on mosses for Engler & Prantl's *Die Naturlichen Pflanzenfamilien*, Whitelegge secured nearly 100 species in 1890–91. In 1892 he compiled a list, revised by Brotherus, of some 300 New South Wales species (Watts & Whitelegge 1902) but this was not published. In 1898 Whitelegge met W.W. Watts and they jointly presented a list of some 500 species for publication by the Linnean Society of New South Wales. Later the manuscript was withdrawn in favour of a broader list (Census) covering Australia. This was published in their joint names in 1902 and 1905, and dealt with the acrocarpous mosses [the pleurocarpous species were published later after their deaths (Burges 1932, 1935)]. Whitelegge's position at the Australian Museum in the early 1900s prevented him from continuing research on mosses and he handed over this activity to Watts.

William Forsyth (1864–1910)

In the 1890s Joseph Henry Maiden, Director of the Sydney Botanic Gardens, encouraged bryophyte collecting and made sure they were included in the collections of the National Herbarium of New South Wales. He delegated William Forsyth to concentrate on bryophytes during general field excursions.

William Forsyth, born near Crieff, Perthshire, Scotland, came from a farming background. In 1886 he became overseer for Centennial Park, Sydney and from 1898 he added to this responsibility for collecting and maintaining bryophytes in the National Herbarium of New South Wales at the urging of Maiden. His enthusiasm for the task resulted in the addition of some 1200 specimens in just two years. He was Curator of Bryophytes from 1898 to 1903 adding many new Australian species during field trips on his own or with Maiden, W.F. Blakely and others to many areas of New South Wales.

His publication *Contribution to a knowledge of the moss flora of N.S.W.* (Forsyth 1899), recorded 61 species of which 43 were new to the colony and 26 were from Port Jackson. In 1900 he added collections from Richmond and Tweed Rivers, New England, Germanton (now Holbrook) and Tumbarumba. He also began an exchange program with overseas bryologists on whom he depended for identifications, in particular Brotherus in Helsinki.

W.W. Watts (1856–1920)

The Rev. William Walter Watts was born in Devon, England. Because of ill health he was sent by his church to Australia in 1887 (Brisbane and later northern New South Wales) to recuperate. He moved to Sydney in 1895. His major collections were made whilst he was minister of the Presbyterian Church in Ballina, far North Coast of New South Wales, and many collections were made at outlying timber camps at a time when the Big Scrub was being cut to open up the land for farming (Ramsay 1980).

In 1909 it was arranged that — "Rev. W.W. Watts and myself [Mr. A.E. Goddard the then curator] shall enter into a complete and detailed examination of the mosses during 1909 from the standpoint of external morphology and histology so that the greatest possible use and value may accrue from the collection in the herbarium." (Sydney Botanic Gardens Annual Report 1909). However, Goddard left for South Africa in 1909 and Watts became Honorary Curator of Cryptogams (1909-1916) until he moved to Victoria. In 1911 the Whitelegge collections, including mosses and lichens, purchased from Goddard, were added to the Herbarium. The collections of W. Forsyth and W.W. Watts (more than 12,000 specimens) were incorporated after their deaths.

Apart from his contributions to bryology in terms of specimens collected, it was Watts' publications with Brotherus and Stephani (17 in all) (Ramsay 1980), that brought the attention of the world to Australian, particularly New South Wales and Queensland taxa (e.g. Brotherus & Watts 1912, 1915, Stephani & Watts 1914 etc). Some 167 new moss species and more than 70 hepatics were named based on Watts' collections.

Study site and collections

Specimens of bryophytes (mosses, hepatics and anthocerotes) were collected in areas of the Royal Botanic Gardens, Government House and Domain over a period of over two years from 1989 to early 1991. This proved to be a particularly good period for bryophyte growth and development as Sydney had above-average rains during much of the time of the study. The majority of collections were made by R.G. Coveny, E.A. Brown and A. Brooks, with some assistance from R. Makinson & J. Wood. Identifications are based on published information in floras, checklists and monographs (Catcheside 1980; Catcheside & Frahm 1985; Crum 1991; Frahm 1985, 1987; Scott 1985; Scott & Bradshaw 1986; Scott & Stone 1976; Touw & Falter-van den Haak 1989. All specimens have been lodged at NSW as vouchers for future studies. An appendix, providing a complete a list of identification numbers for the vouchers, will be deposited in the library at NSW.

The areas investigated were the Royal Botanic Gardens (RBG), Government House gardens and the Domain (Fig. 1). The names for sections of the Botanic Gardens (Palace, Upper, Middle and Lower) are indicated on Fig. 1 by number and used here for convenience to describe the features of the areas.

1. The Palace Garden — bounded by Macquarie Street and the Cahill Expressway and south of the Conservatorium of Music — includes various garden beds, the Rose Garden, stone walls, lawns and paths. A sunken garden, the Memorial Garden to Pioneers (Men and Women), is located in this area.

2. The Upper Garden — trees, lawns, garden beds, stone paths and walls lie adjacent to this but are separated from the Palace Garden by the Nursery behind the Pyramid and the Arc glasshouses of the Tropical Centre. The eastern border is on Mrs Macquaries Road where the Anderson, Brown and Cunningham buildings are located.

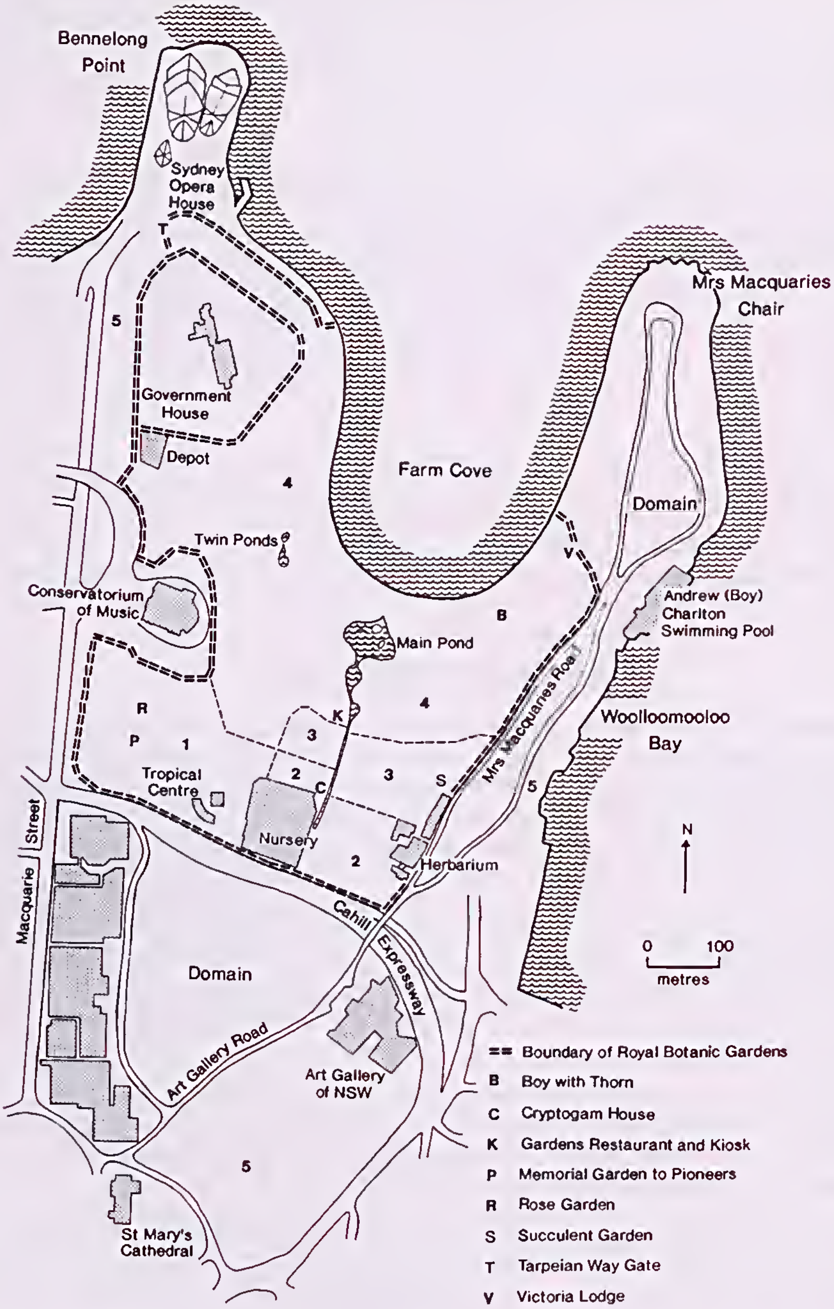

Figure 1. Map of the Royal Botanic Gardens Sydney, the Domain and adjacent areas showing the main collection sites referred to. 1. The Palace Garden. 2. The Upper Garden. 3. The Middle Garden. 4. The Lower Garden. 5. The Domain. Modified from 1990 general map published by the Royal Botanic Gardens, Sydney.

3. The Middle Garden — includes a succulent garden on Mrs Macquaries Road, a large brick-walled creek (known as Botanic Gardens Creek), part of a palm grove to the west, scattered large trees and formal gardens.

4. The Lower Garden — adjacent to Farm Cove and extending from Mrs Macquarie's Road to the Opera House; in the centre Botanic Gardens Creek feeds into the Main Pond, the Gardens Restaurant being above the ponds. Large trees, garden beds, paths and sandstone outcrops occur in this area. The Boy with Thorn statue and Tarpeian Way Gate are also in this area.

5. The Domain — extends both south of the Cahill Expressway, opposite and beside the Art Gallery, then north of the Expressway along Mrs Macquaries Road and Woolloomooloo Bay and past the Andrew Charlton Pool to Mrs Macquaries Chair. Also included is a narrow strip between the Gardens and Macquarie Street towards the Opera House.

The habitats of particular significance for bryophytes in the Royal Botanic Gardens include the brick and stone-walled Botanic Gardens Creek, Twin Ponds and island near the Gardens Restaurant, grounds outside the Tropical Centre glasshouses, potting shed and nursery glasshouses, paths and lawns, sandstone walls and stairs, large sandstone outcrops and old cut rock-faces in the Domain, near Mrs Macquaries Chair and near the Opera House, and the bark of trees.

Bryophytes present in the Royal Botanic Gardens, Government House and the Domain, Sydney.

We present here annotated species lists for 1.) Mosses and 2.) Hepatics and Anthocerotes, with expanded notes on mosses not described in detail in Scott & Stone (1976) or Catcheside (1980), and hepatics not mentioned in Scott (1985). Distribution notes for mosses refer to Ramsay (1984) where previous records are given for the Central Coast of New South Wales (CC), in which the Royal Botanic Gardens lie. As there are no details for the distribution of hepatics within New South Wales we referred to Scott (1985) for records of species present in New South Wales.

Species previously collected in the Gardens include *Fabronia australis* as *F. tayloriana* by W.W. Watts in 1910 and 1914); *F. scottiae* by W. Forsyth in 1899, W.W. Watts in 1899 and 1910; Lovegrove in 1901 and E. Cheel in 1901; *F. brachyphylla* by W. Forsyth in 1900); *Vescicularia* sp. on pots in fernhouse. The only previous hepatic specimen in NSW from the Royal Botanic Gardens is *Lunularia cruciata* (L.) Dumort. collected by A.N. Rodd in 1964 near the glasshouses.

1. Annotated species list of mosses of the Royal Botanic Gardens (RBG), Government House and the Domain.

+ not previously reported for Central Coast (CC) in New South Wales (Ramsay 1984). If a species has been collected only once or twice previously Ramsay has noted this.

++ new record for N.S.W.

Sphagnaceae

Sphagnum cristatum Hampe. Present in pots with insectivorous plants in the potting shed – probably brought in for soil improvement. Naturally occurring in soak areas.

Archidiaceae

Archidium wattsii (Broth.) Stone [syn. *Splachnobryum wattsii* Broth. fide Stone 1984: 153-157.]. Domain near Mrs Macquaries Point, on sandstone rock near retaining wall.

This species was originally known only from two specimens, collected at Watsons Bay and Parsley Bay 1899 (*Watts 2450, 2479*) Sydney but has now been reported from Queensland by Stone (1984). It is the first species of *Archidium* confirmed for N.S.W.

Dawsoniaceae

Dawsonia polytrichoides R. Br. Brought in with plant material in nursery pot although this species does occur in wet forested valleys in the region.

Fissidentaceae

Fissidens dietrichiae C. Muell. On wall of Botanic Gardens Creek. This name is listed in error as a synonym for *F. crassipes* Wils. ex B.S.G. for New South Wales in Ramsay (1984). *F. crassipes* has not been found in Australia (Stone pers. comm.). Previously recorded from fewer than three collections for CC.

Fissidens leptocladus C. Muell ex Rodw. On moist brickwork of Botanic Gardens Creek, on brickwork and soil on hillside near the Opera House, near the Government House Depot, and in Domain overlooking Woolloomooloo Bay. Known from fewer than three collections in CC.

Fissidens linearis Brid. var. linearis [fide Stone 1991: 403-405; syn. *F. humilis* Dix. & Watts and syn. *F. aeruginosus* Hook. f. & Wils. var. *arcuatulus* Stone fide Stone 1990: 245-260]. Botanic Gardens Creek, Domain near Andrew Charlton Pool, on earth bank among rocks on Mrs Macquaries Point. Common species of wet earth banks.

Fissidens oblongifolius Hook. f. & Wils. On sandstone rocks between the Brown and Cunningham Buildings.

Fissidens perangustus Broth. On soil in Pioneer Memorial Garden in RBG and Domain overlooking Woolloomooloo Bay. Listed by Watts & Whitelegge (1902) for New South Wales but not confirmed in Ramsay (1984, p. 513)

Fissidens pungens C. Muell. & Hampe. Common in various areas, floor of large drain, on small island near Kiosk, soil near Pyramid glasshouses, steps near Government House, between the large pond and Gardens Restaurant. Common on soil.

Fissidens semilimbatus C. Muell. & Hampe [listed as a synonym of *F. taylorii* C. Muell. in Ramsay (1984) and Scott & Stone (1976) but now considered a separate species (Stone pers. comm.)]. On spillway of Botanic Gardens Creek, on brickwork near the Cryptogam House, Domain on moist sandstone rock. Common in CC area.

Fissidens rigidulus Hook. f. & Wils. subsp. *rigidulus*. An aquatic species found here only on brickwork of Botanic Gardens Creek below water level. Confined to running water, known from fewer than three collections from CC.

Ditrichaceae

Ceratodon purpureus (Hedw.) Brid. subsp. *convolutus* (Reichdt) J.S. Burley [fide Burley & Pritchard 1990: 17-76]. Collected on brickwork in Domain, near Conservatorium and Government House on soil and in soil in cracks near Botanic Gardens Creek. A cosmopolitan species, commonly occurring as coloniser of disturbed soil.

Ditrichum difficile (Dub.) Fleisch. In soil on sandstone cliff overlooking the Opera House. Frequently found on earth banks.

Dicranaceae

Campylopus bicolor (F. Muell.) Wils. var. *bicolor*. On soil outside Herbarium buildings and on rock in Domain near Mrs Macquaries Chair.

Campylopus clavatus Hook. f. & Wils. On pots in nursery. Generally common on rocks.

Campylopus incrassatus C. Muell. On soil cracks on wooden bridge over Botanic Gardens Creek. Recorded as *C. flavo-viridis* Dus. [fide Catcheside & Frahm 1985: 363] = *C. incrassatus* [fide Frahm 1987: 715].

Campylopus introflexus (Hedw.) Brid. Young plants in crevices of bark on *Brachychiton rupestre* with *Tortula pagorum* and lichen, sandstone rocks and near Andrew Charlton Pool in Domain. Lacking the usual hyaline apex but clearly *C. introflexus* from leaf sections. Common coloniser of rocks.

Campylopus pyriformis (Schultz) Brid. Domain near Andrew Charlton Pool, Mrs Macquaries Chair and on old cut sandstone cliff opposite the Opera House. Recorded as *C. pallidus* Hook. f. & Wils. from CC [synonyms *C. novae-valesiae* Broth., *C. woollsii* (C. Muell.) Par. fide Frahm 1987: 720; *C. pallidus* fide Corley & Frahm 1982 : 187–190].

Dicnemoloma pallidum (Hook.) Wijk & Marg. On rock near the Brown Building. Common coloniser of sandstone rocks.

Trematodon suberectus Mitt. On soil on brick in nursery.

Leucobryaceae

++*Leucobryum aduncum* Dozy & Molk. On soil at base of *Ficus rubiginosa*. This species was identified by D.G. Catcheside. Although not previously reported from N.S.W. many specimens have probably been misidentified as *L. candidum*.

Pottiaceae

Barbula calycina Schwaegr. In lawn with other mosses below and east of Succulent Garden and wall, RBG. A common moss of disturbed soil.

Barbula unguiculata Hedw. On Boy with Thorn Statue, on moist soil in lawns in RBG. Common coloniser of soil.

Gymnostomum calcareum Nees & Hornsch. [= *G. aeruginosum* Sm. fide Zander 1977: 233–269, see note in Catcheside 1980: 187]. On moist old cut sandstone cliff overlooking the Opera House and on calcareous soil in the Domain. A calcareous moss suggesting that the sandstone rock surface possibly had a surface wash of cement dust or other calcareous material.

Pottia truncata (Hedw.) B.S.G. on soil in lawn – Domain, Government House and near the Tarpeian Way Gate. Common coloniser of soil.

Tortula muralis Hedw. On sandstone blocks near Government House, common on cement in brick walls, footpaths, stonework of Botanic Gardens Creek, near Andrew Charlton Pool in Domain and at Mrs Macquaries Point. Common on calcareous brickwork, and rocks.

Tortula pagorum (Milde) De Not. Common on bark of trees such as *Lophostemon confertus, Fraxinus chinensis, F. Xcanadensis, Populus* sp., *Ficus hillii, F. bengalensis, F. macrophylla, Schinus areira, Magnolia grandiflora*, on brickwork of Succulent Garden and cement steps of Rose Garden. Frequent epiphyte on rough-barked trees.

Tortula papillosa Wils. Uncommon in RBG, epiphytic on *Bauhinia patersoniana* in Gardens [tree since removed] and on tree in Government House Grounds. Known from fewer than three collections in CC.

Weissia controversa Hedw. var. *controversa* Hedw. Common on soil on brickwork in the Gardens, and near the Tarpeian Way Gate and Cryptogam House. Very common on soil.

+*Weissia controversa* Hedw. var. *gymnostoma* (Dix.) Sainsb. [Capsule was clearly gymnostomous] near Boy with Thorn Statue.

Ptychomitriaceae

Ptychomitrium australe (Hampe) Jaeg. Sandstone rock near Herbarium buildings and Government House. Recorded from fewer than three collections in CC.

Funariaceae

Funaria hygrometrica Hedw. On soil in Domain, on pots in glasshouse, old rose garden and in nursery garden bed near the Gardens Restaurant. Very common weed in pots in nurseries and as a coloniser of soil after fires.

Bryaceae

Bryum argenteum Hedw. Common on soil in footpaths and brick walls throughout the Gardens and Domain, cement in walls of Government House and in cracks of wall of Botanic Gardens Creek. Common on calcareous substrata particularly paths and walls.

Bryum billardierei Schwaegr. var. *billardierei*. On walls of Botanic Gardens Creek, soil and in crevices in rock wall near Andrew Charlton Pool. A common moss of damp soil.

Bryum capillare Hedw. Garden bed, on pots in nursery, wall of Botanic Gardens Creek, on soil and sandstone rock overhang in Domain.

Bryum ?chrysoneuron C. Muell. Near swimming pool in Domain.

Bryum dichotomum Hedw. Common on soil and brickwork in RBG, pots in nursery, glasshouses, footpaths, sandstone rock near Brown Building, brickwork in Succulent Garden and sandstone rock near Conservatorium, on tree bases and sandstone blocks near Government House, on brickwork and sandstone rocks in the Domain and at Mrs Macquaries Chair. Common colonist of soil.

Bryum pachytheca C. Muell. Brickwork and wall in Pioneer Memorial Garden.

++*Bryum rubens* Mitt. Soil outside Pioneer Memorial Garden. No previous report of this moss for N.S.W. [some earlier collections included in the *B. erythrocarpum* complex may be this species. Refer to Catcheside 1980: 277]

Bryum ?sauteri B.S.G. On sandstone rock outside Brown Building. Another member of the *B. erythrocarpum* complex. Collected fewer than three times in CC.

+*Bryum subapiculatum* Hampe. Southern side of Botanic Gardens Creek, on soil in Domain near Mrs Macquaries Point.

Bryum subfasciculatum (Hampe) Mitt. Common in wet soaks in grass in RBG, on soil at base of trunk of *Brachychiton rupestre*, grass near Government House and with wet grass in Domain. Frequent on soil.

Bryum torquescens Bruch ex De Not. On pots in nursery. (Previously published as *B. capillare* ssp. *torquescens* (De Not.) Kindb.)

Leptobryum pyriforme Hedw. Soil in pots in nursery, and in Depot near glasshouses, on sandstone overhang in Domain [plants of this species covered in rhizoidal gemmae were collected in Hyde Park in Central Sydney]. Common weed of pots in nurseries.

Orthodontium lineare Schwaegr. subsp. *sulcatum* (Hook. f. & Wils.) Meijer. On moist soil at Government House and twin ponds. More commonly found on burnt logs in forests.

Pohlia tenuifolia (Jaeg.) Broth. On soil with other mosses including *Barbula calycina* in RBG. Known from fewer than three collections in CC.

Aulacomniaceae

Aulacomnium palustre (Hedw.) Schwaegr. Found with *Dawsonia polytrichoides* and with *Bryum billardierei* on pots in potting shed. The presence of pseudopodia bearing leaf-like gemmae is characteristic. As all previous New South Wales reports are from the North Coast and Southern Tablelands, this is most likely an introduction from elsewhere.

Bartramiaceae

+*Philonotis ?austrofalcata* Broth. & Watts. The only previous locality in New South Wales is Yarrangobilly in the Southern Tablelands (ST). This may be an introduction to CC.

Philonotis dicranellacea (C. Muell.) Watts & Whitel. On moist sandstone rocks near Govt. House, on sandstone rocks on earth embankment in Domain and near Andrew Charlton Pool.

Philonotis tenuis (Tayl.) Reichdt. On pots in nursery, glasshouses with *Funaria hygrometrica*, brick wall in Royal Botanic Gardens, on damp soil below hanging rock and on sandstone rocks near Andrew Charlton Pool in Domain. Common in seepage areas or under rocks.

Fabroniaceae

Fabronia australis Hook. Epiphytic on trees, e.g. trunk of Rosaceous tree, southern side of trunk of *Pyrus calleryana*, on *Ficus macrophylla*, on base of trunk of *Macrozamia communis* in RBG and in Government House gardens. Collected fewer than three times in CC.

Fabronia ?brachyphylla C. Muell. Rose garden near Conservatorium, on base trunk of *Glochidion ferdinandi* and on trunk of *Diospyros digyna*.

Fabronia scottiae C. Muell. Stem of Rosaceous tree, base of *Olea europaea* subsp. *europaea*, trunk of *Ficus macrophylla*, base of trunk of *Macrozamia communis* in Royal Botanic Gardens and on wall near Andrew Charlton Pool in Domain.

Racopilaceae

Racopilum cuspidigerum (Schwaegr.) Aongst. var. *cuspidigerum* Common on pots in nursery, on stonework of Botanic Gardens Creek, on brickwork near nursery, on sandstone near Brown Building, on grass beneath *Liquidambar* and other trees, on brickwork and floor of Cryptogam house, near glasshouses, near Opera House gate, on soil near ponds and on rockface near Andrew Charlton Pool in Domain. Common coloniser of soil.

Ptychomniaceae

Hampeella pallens (Lac.) Fleisch. On bark of the palm *Jubaea chilensis* in garden bed in Royal Botanic Gardens. Mostly found in wet forests as an epiphyte.

Lembophyllaceae

Camptochaete gracilis (Hook. f. & Wils.) Par. [= *Fallaciella gracilis* (Hook f. & Wils.) Crum fide Crum 1991: 313-322]. On trunk of *Ceratonia siliqua* in garden bed betweeen Government House and the Twin Ponds. Occurs mainly in wet forests on rocks.

Hypopterygiaceae

Hypopterygium rotulatum (Hedw.) Brid. On moist sandstone rock near Opera House Gate. Mostly found on wet rocks in valleys and forests.

Thuidiaceae

Thuidium sparsum (Hook. f. & Wils.) Jaeg. Brickwork of Botanic Gardens Creek, brick wall of Pioneer Memorial Garden with *Tortula muralis, Bryum dichotomum, Fissidens pungens, Lunularia cruciata,* Opera House Gate, Government House grounds and on soil and stone walls in the Domain. Common species on rocks and soil in CC. [previously reported as *T. furfurosum* e.g. Scott & Stone (1976) fide Touw & Falter-van den Haak 1989: 1–57]

Leskeaceae

Pseudoleskeopsis imbricata (Hook f. & Wils.) Ther. [*Pseudoleskea imbricata* (Hook. f. & Wils.) Broth.]. Sandstone rock wall and sandstone outcrop in Domain near Mrs Macquaries Chair. Known to occur on calcareous substrates. The calcareous nature of this moss suggests that the sandstone rocks had some calcareous material on the surface.

Amblystegiaceae

+*Amblystegium serpens* (Hedw.) B.S.G. Stone walls of Botanic Gardens Creek. New generic record for CC.

Brachytheciaceae

Brachythecium rutabulum (Hedw.) B.S.G. Glasshouses in Nursery.

Eurhynchium muricatulum (Hook. f. & Wils.) Jaeg. Sandstone rocks outside laboratory in Brown Building. Recorded from fewer than three specimens in CC.

+*Kindbergia praelonga* (Hedw.) Ochyra [formerly *Eurhynchium praelongum* (Hedw.) B.S.G. fide Ochyra 1982: 54]. On stone walls of Botanic Gardens Creek and on soil on island near Gardens Restaurant. No report in Ramsay (1984) for N.S.W. but there is a recent record for Sydney by Downing (1989: 6).

Plagiotheciaceae

Rhynchostegium patulum Jaeg. On moist soil in Domain. Previously collected from the area around Port Jackson, Sydney.

Rhynchostegium tenuifolium Hedw. Moist soil with *Racopilum* on island near Gardens Restaurant. This species occurs on logs and soil.

Sematophyllaceae

Sematophyllum homomallum (Hampe) Broth. On stone walls of Botanic Gardens Creek, epiphytic at base of *Eucalyptus saligna* with *Tortula pagorum*, occasionally on trunk of of rough barked trees e.g. *Jubaea* sp., *Rothmannia globosa* also with *T. pagorum.*

+*Sematophyllum contiguum* (Mitt.) Mitt. Wall of Botanic Gardens Creek, rock in Domain.

Sematophyllum aciculum (Broth. ex Dix.) Dix. Glasshouses near Nursery, in Domain and at Mrs Macquaries Point. Reported from Port Jackson, Sydney.

Hypnaceae

Isopterygium ?minutirameum (C. Muell.) Jaeg. On soil near Depot.

?*Isopterygium albescens* (Hook.) Jaeg. In moist crevices of sandstone rock in Domain toward Mrs Macquaries Point.

In addition there are a number of undetermined sterile pleurocarpous moss species possibly from the families Hookeriaceae and Brachytheciaceae.

2. Annotated species list of hepatics and anthocerotes of the Royal Botanic Gardens, Government House and Domain.

+ not previously recorded for N.S.W.

++ not previously recorded from Australia

Anthocerotes

Anthoceros cf. *punctatus* L. On moist soil outside Ranger's cottage (Victoria Lodge) and on soil (now dug over) near Andrew Charlton Pool in Domain.

Hepatics

Aneuraceae

+*Riccardia bliklika* Hewson. On treefern fibre in orchid glasshouse in Nursery. A Queensland species probably brought in from there.

Riccardia ?macdonaldiana Hewson. Male plants only, on sandstone rock outside laboratory in Brown Building. A Queensland species probably brought in from there.

Pallavaciniaceae

+*Pallavicinia lyellii* (Hook.) Carruth. On stone walls of Botanic Gardens Creek, moist soil near Gardens Restaurant. Not recorded for N.S.W. by Scott (1985) or Scott & Bradshaw (1986).

Metzgeriaceae

Metzgeria decipiens (Mass.) Schiffner & Gottsche. On trunk of tree fern *Cyathea leichhardtiana* near Gardens Restaurant. Recorded as a common epiphyte in wet forest in N.S.W. Probably brought in on the *Cyathea* trunk.

Aytoniaceae

Asterella drummondii (Hook. f. & Tayl.) R.M. Schuster. In pot in nursery. Common on soil crusts.

Marchantiaceae

Lunularia cruciata (L.) Dumort. On stone walls of Botanic Gardens Creek, brickwork in Pioneer Memorial Garden, on soil and stonework of steps overlooking Woolloomooloo Bay in the Domain. Common on soil in the Sydney area and throughout N.S.W.

Marchantia polymorpha L. On soil in pots in nursery in RBG. A common weed of glasshouses in N.S.W.

Ricciaceae

Riccia asprella Carring. & Pears. Outside Government House on black loamy soil.

Riccia bifurca Hoffm. Outside Government house on black loamy soil. Occurs on damp loamy soils often under grass in N.S.W.

Riccia cartilaginosa Stephani. Outside Government House on black sandy loam and on moist sandy soil at edge of sandstone rocks in Domain. Found on wet soil in forest clearings in N.S.W.

Riccia aff. *spongiosula* Na Thalang. Outside Government House on black loamy soil.

Occurs in dry, hot regions of N.S.W.

[Note: all the *Riccia* species, which tend to occur in drier areas, may have been brought in as spores with soil].

++Chonecoleaceae

++*Chonecolea doellingeri* (Nees) Grolle. On bark of various phorophytes, e.g. *Olea europa* subsp. *africana, Eucalyptus saligna, Pinus roxburghii, Quercus cerris, Jubaea chilensis, Beilschmiedia elliptica* and the trunk of *Macrozamia communis*, on bark of *Ficus macrophylla* and *F. hillii* in the Domain, outside Government House on bark of *Harpephyllum caffrum* and *Eucalyptus robusta*. This is the first record of this family, genus and species from Australia. *Chonecolea* is a native of Brazil, the lowlands of subtropical South America and of subtropical Florida. This species is thriving and is found throughout the RBG. It also occurs in adjacent areas having been collected near St Mary's Cathedral but has not been found on the northern shores of Sydney Harbour. This species may have arrived as a propagule and become naturalised here.

Lepidoziaceae

Kurzia hippurioides (Hook. f. & Tayl.) Grolle. In crevice below moist sandstone rock overhang in the Domain.

Lepidozia laevifolia (Hook. f. & Tayl.) Taylor ex Gottsche et Nees & Lindenb.). On rotting log in rainforest area of RBG.

Geocalycaceae

Chiloscyphus novae-zelandiae (Lehm. & Lindenb.) Engel & Schust. Near Pyramid glasshouse at base of fern *Angiopteris erecta*. Generally found on fallen logs in N.S.W. forests.

Chiloscyphus semiteres (Lehm.) Lehm. & Lindenb. [syn. *Lophocolea semiteres*]. On brickwork of Botanic Gardens Creek, base of the fern *Todea barbara* and the palm *Livistona* sp. outside Gardens Restaurant, brickwork of Cryptogam House, outside Government House and on moist sandstone steps and moist soil at edge of sandstone rocks in the Domain. Common as an epiphyte or on fallen logs in forests in N.S.W.

Chiloscyphus sp. Stonework of Botanic Gardens Creek.

Frullaniaceae

Frullania monocera (Hook. f. & Tayl.) Taylor ex Gottsche, Nees & Lindenb. On bark of *Quercus cerris* (tree since removed) in RBG.

Frullania pentapleura Tayl.On bark of various phorophytes e.g. *Fraxinus, Quercus, Jubaea chilensis* and *Rothmannia globosa*, outside Government House on *Quercus palustris*. Occurs as an epiphyte or on rocks in N.S.W.

Frullania ?probosciphora Tayl. On bark of *Brachychiton rupestre* near statue of Boy with Thorn (Lower Garden).

Codoniaceae

Fossombronia caespitiformis De Not. ex Rabenh. On moist ground amongst mosses below sandstone rocks at edge of Mrs Macquaries Road in the Domain. Common in Eastern mainland Australia including N.S.W..

Fossombronia sp. Sterile material only, unable to be identified to species without spores. On pot in nursery, growing amongst mosses and *Riccia cartilaginosa* at base of sandstone rocks in Domain.

Lejeuneaceae

+*Cololejeunea ?minutissima* (Sm.) Schiffn. On bark of *Liquidambar* near Twin Ponds, bark of *Rothmania globosa* and a rough-barked tree in garden beds near walled section of Botanic Gardens Creek.

Lopholejeunea sp. In glasshouse amongst mosses at base of orchid stems (*Dendrobium* sp.) in pot and tree fern fibre amongst mosses.

Conclusions

The Royal Botanic Gardens provided an interesting site for study of bryophytes, as the area has been subject to disturbance since settlement. The species present include some native locally and possibly continuously present since early settlement days, as well as opportunistic forms that have invaded by dispersed diaspores, and some species imported on soil or with plants.

In this study 95 species of bryophytes (70 mosses, 24 hepatics and one anthocerote) were collected. A wide range of families is represented: 24–25 families of mosses of which 12 are acrocarpous and 12 pleurocarpous; 13 families of hepatics of which 6 are thallose and 7 leafy. The genera with most species are Bry*um* (10 species), *Fissidens* (8) *Campylopus* (5), *Fabronia* (3), *Tortula* (3), *Chiloscyphus* (4), *Riccia* (4).

Taxa present can be grouped according to their life strategies and/or habitat preferences.

1. Colonising opportunistic species mainly on soil include *Bryum dichotomum, Ceratodon purpureus, Ditrichum difficile, Fissidens* spp., *Funaria hygrometrica, Racopilum cuspidigerum, Weissia controversa, Riccia* spp.,

2. Epiphytic species common in the gardens are *Fabronia* spp., *Tortula pagorum, Frullania* sp.

3. Mosses most commonly found on calcareous substrata are *Bryum argenteum, Gymnostomum calcareum, Pseudoleskea imbricata, Tortula muralis.*

4. Colonisers of rocks include *Campylopus* spp., *Dicnemoloma pallidum, Ptychomitrium australe.*

5. Aquatic species present are *Fissidens rigidulus, Sphagnum cristatum.*

A new record for Australia is the liverwort *Chonecolea doellingeri* (Nees) Grolle (identified by R. Grolle) and a new moss record for New South Wales is *Leucobryum aduncum* Dozy & Molk. (identified by D.G. Catcheside; many specimens which may be this have probably been identified erroneously as *L. candidum*). Species present in other regions of N.S.W. but not previously reported for the Central Coast (Ramsay 1984) include *Amblystegium serpens, Bryum rubens, B. subapiculatum, Kindbergia praelonga, Philonotis ?austro-falcata, Sematophyllum contiguum, Weissia controversa* var. *gymnostoma.* Some species listed as having only one or two collections in CC by Ramsay (1984) include *Fabronia australis, Fissidens leptocladus, F. rigidulus, Tortula papillosa, Ptychomitrium australe.* Hepatics not listed for New South Wales by Scott (1985) include *Pallavicinia lyellii, Riccardia bliklika, R. macdonaldiana, Cololejeunea minutissima.*

Species most likely to have been introduced to Australia rather than being native here are *Kindbergia praelonga* (Hedw.) Ochyra (formerly *Eurhynchium praelongum* (Hedw.) B.S.G.), *Leptobryum pyriforme* Hedw. and *Chonocolea doellingeri* (Nees) Grolle.

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Mangrove, saltmarsh and peripheral vegetation of Jervis Bay

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Abstract

Clarke, P.J. CSIRO Division of Fisheries, P. O. Box 94, Vincentia, NSW, Australia 2540) 1993. Mangrove, saltmarsh and peripheral vegetation of Jervis Bay.* Cunninghamia *3(1): 231–254.* Studies of the mangrove and saltmarsh vegetation of Jervis Bay were undertaken for inventory and baseline purposes. Vascular plant species composition, distribution and abundance were quantitatively measured. The vascular flora consists of about 140 species, of which 15 are introductions. Nine species are found at or near their distributional limits around Jervis Bay. The major ordination axes are interpreted as elevation and variability in moisture content. Classification of sites produced 12 complexes after fusion of 30 smaller groups. These complexes have the provisional rank of an association in phytosociology and can be recognised on aerial photographs. The area contains a number of species and vegetation types that are rare or absent from other locations in NSW. Jervis Bay is now a reference system against which changes in the distribution and abundance of intertidal vascular plants can be measured. Such information is fundamental to the management of Jervis Bay and other areas of estuarine vegetation in NSW.

Introduction

Mangroves and saltmarshes are plant assemblages that are periodically inundated with seawater and usually grow in waterlogged saline soils. In Jervis Bay, mangrove and saltmarsh plants are mainly found in six estuaries, although smaller pockets occur in minor creeks, lagoons and on rock platforms. General descriptions of the extent and composition of the vegetation are given in Adam and Hutchings (1987), and West (1987). Major mangrove, saltmarsh and seagrass stands have also been mapped by West *et al.* (1985) at a scale of 1:25 000 based on limited ground truthing.

A baseline study of the mangrove and saltmarsh vegetation was initiated in 1987 as a part of a major study of the marine environment in Jervis Bay. Detailed quantitative information on the distribution, abundance and performance of mangrove and saltmarsh vegetation was required as reference or baseline data, so that any change could be detected after developments in the bay. Such detailed data prior to major developments have been generally lacking for many Australian ecosystems.

Measures were made at the assemblage, population and individual levels of biological organisation over a wide range of spatial and temporal scales. This paper describes: 1) the species composition of the vegetation, 2) the distribution of species across environmental gradients, 3) the population structure of the major species, and 4) the assemblage or community patterns.

Study site

Jervis Bay is a circular marine embayment (35° 07'S, 150° 42'E) with a maximum depth of 30 m and a surface area of 102 km^2. In comparison with other embayments, the c. 400 km^2 catchment of Jervis Bay is small relative to the surface area of the bay (West

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1987). The mangrove, saltmarsh and fringe forests are found in the tidal creeks that enter the bay and in a few instances on rock platforms. The climate is mild with a mean daily temperatures range of 13.6°C to 19.9°C. The mean annual rainfall for Point Perpendicular is 1230 mm, although the mean rainfall was higher from 1986 to 1991 (c. 1500 mm). Rainfall along the Illawarra section of the south coast is several hundred mm higher than that recorded for the far south coast. The tides in Jervis Bay are semidiurnal with a maximum range of about 2.2 m; the range is attenuated in the tidal creeks and inlets. Anthropogenic influences on the mangroves, saltmarsh and fringe forests have been moderate with some historic clearing and draining, currently these influences are limited to occasional incursions by trail bike or four wheel drive vehicles.

Methods

Survey design

Sampling was designed to measure variables over hierarchies of space and time so that estimates of spatial and temporal variance could be made (see Underwood 1991). In the case of long-lived mangrove and saltmarsh plant species, the survey was designed to assess spatial variation in the distribution and abundance of mangrove and saltmarsh species. Six tidal inlets were sampled in Jervis Bay: Cararma Creek; Wowly Gully; Callala Creek; Currambene Creek; Moona Moona Creek; and Flat Rock Creek (Figure 1). Each inlet was divided into 500 m sections and transects were randomly placed in these sections at right angles to zonation of vegetation. Adjacent to each transect, 50 X 20 m plots were established. These plots were subjectively located at low, mid and high tidal elevations in structurally similar vegetation. Four replicate quadrats of 5 X 5 m were placed within these plots in a random manner (Figure 1).

Species composition and distribution

Floristic lists were compiled from quadrat, transect samples and field reconnaissance. Voucher specimens have been collected for most species and are held by the John Ray Herbarium at The University of Sydney. Identifications were determined by the Royal Botanic Gardens, Sydney. Nomenclature follows that used by Jacobs and Pickard (1981) and Harden (1990, 1991).

Estimates of cover for each species present in quadrats were made in the following classes: 1 (less than 5%), 2 (5–20%), 3 (21–50%), 4 (51–80%), 5 (81–100%). In order to obtain inforation on the structure of mangrove communities, *Avicennia marina sensu lato* was divided into five classes based on information about tree height and shape. These classes (attributes) were: seedlings; shrubs <2 m; shrubs 2–5 m; single-stemmed trees >5 m; and multi-stemmed trees >5 m. Measures of cover were initially made from December 1988 to February 1989. A random subset of plots in four creeks was resampled from April to July in1991 so that temporal comparison of species richness could be made. These data were analysed in a mixed ANOVA where time, creeks, and plots nested in creeks were treated as random factors, but elevation was treated as a fixed factor.

The presence/absence of plant species along each transect was also recorded at contiguous one metre intervals. These data were summed for ten metre lengths of each transect to provide frequency data for interpretation of aerial photography. Data for each creek were summed to provide an overall view of the most common species in

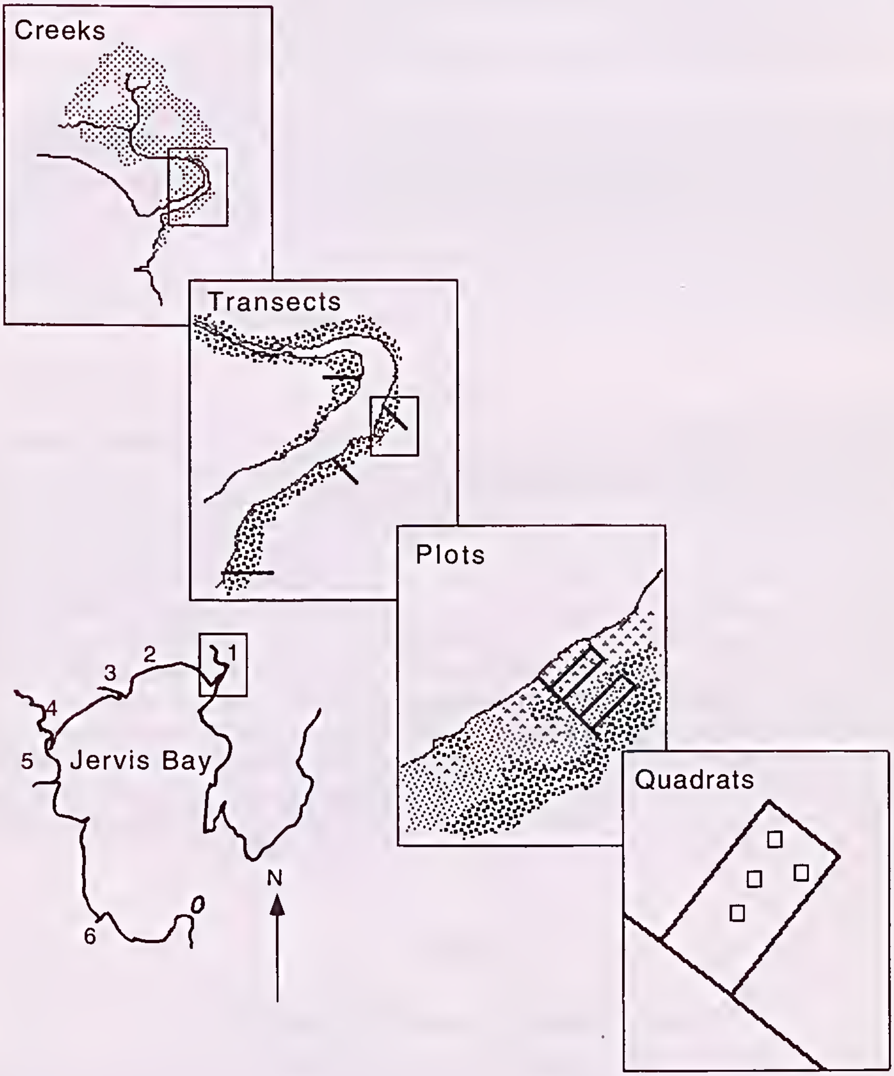


Figure 1. Diagrammatic representation of spatial hierarchies of sampling.

Jervis Bay. In addition to the summed transect data, finer resolution data were collected along four transects in both Cararma Creek and Moona Moona Creek. For each of these transects, the presence of species and the ground elevation were measured at one metre intervals.

Population measures

The density, height and girth of species that were common and could be counted as genets were recorded in the same stratified manner as the multivariate data. Subsets of these data were selected for balanced univariate analyses. Nested analyses of variance (ANOVA) were performed for each variable measured on each species; all spatial factors (plots, transects and creeks) were treated as random factors. Data were tested for homogeneity and no transformations were required. The skewed distributions of some data were not normalised as in most cases they were unimodal.

Ordination and classification of plant communities

Ordination and classification was performed only on quadrat data collected from the 1988–1989 samples (412 quadrats). Both sites (objects) and species (attributes) were classified into groups using a polythetic hierarchical divisive classification (TWINSPAN, Gauch 1982), and agglomerative hierarchical classification using the Bray–Curtis association measure with flexible UPGMA sorting strategy (PATN, Belbin 1987). The gradational nature of these data was explored through ordination and direct gradient (transect) analysis. Indirect gradient analysis using hybrid non-metric multidimensional scaling was used to ordinate the site data (Faith *et al.* 1987).

Mapping

Maps of the major plant community types were prepared from enlarged black and white aerial photography. Colour infra-red photographs were taken in January 1989 from a height of 2286 m (scale 1:15 000) by the NSW Land Information Group. The photographic prints were examined and selected frames were enlarged and rectified to 1:4 000 scale by the Australian Land Information Group. Boundaries of the main vegetation types were drawn onto clear film overlays with a 0.35 mm drafting pen. Boundaries were determined using an iterative process of comparing: (1) structural differences on the enlarged images; (2) tonal differences on the enlarged images; (3) colour differences on contact prints; (4) ground transect data; and (5) general ground reconnaissance. Delineation of patchy mangroves proved difficult so canopy gaps were drawn only where they exceed four metres in circumference on the ground. The clear film overlays were subsequently scanned and the digital data reduced to vectors for data management in a GIS and for cartographic output. Copies of the maps are not reproduced here, but will archived in the library at the Royal Botanic Gardens, Sydney, and the library of CSIRO Division of Fisheries, Hobart.

Results

Species composition and distribution

The seagrass, mangrove, saltmarsh and fringe flora of Jervis Bay contains at least 140 species of vascular plants (Appendix 1). The mangrove and saltmarsh vascular flora consists of about 38 species, of which five are exotic. The fringe forest flora is more diverse, containing 80 species with 11 introductions. About 103 species of vascular plants were recorded in transects and 65 species were recorded in quadrat samples.

Nine vascular plant species have been found at or near their geographical limits of distribution in Jervis Bay. Their distribution and population status, based on general observations, are briefly outlined (Table 1) which shows the concentration of these species in the Cararma Creek and Wowly Gully saltmarshes.

Differences in species richness in 5 X 5 m quadrats were detected among plots, elevations and creeks, but not among combinations of space and time (Table 2, Figure 2). Significant differences were detected across time, but the magnitude of the difference, (less than one species) was so small that it seemed to be of little biological importance.

Caution should be used in comparing summed frequencies for common species across different creeks because no statistical comparisons of frequencies within or between creeks have been performed. The relative abundance, however, indicates changes in species dominance among creeks (Figure 3a–f). Summed data for all creeks provided an overall view of the relative composition for all transects in Jervis Bay (Figure 3f), and indicates that the saltmarsh graminoids were predominant at sites sampled.

Table I Estimates of abundance of saltmarsh species of biogeographic interest in Jervis Bay. + = populations with < 100 plants or < 100m^2 cover, ++ = populations 100–1000 plants or 100–1000m^2, +++ = populations >1000 plants or > 1000m^2. A = Cararma Creek, B = Wowly Gully, C = Callala Creek, D = Currambene Creek, E = Moona Moona Creek, F = Other Locations

Species	A	B	C	D	E	F
Atriplex cinerea	+	-	-	-	-	+
Cuscuta tasmanica	-	++	-	-	-	-
Disphyma clavellatum	-	-	-	-	-	+
Distichlis distichophylla	-	++	-	-	-	-
Gahnia filum	+++	++	+++	+	++	+
Limonium australe	+	-	++	-	+	-
Sclerostegia arbuscula	+++	-	-	-	-	-
Stipa stipoides	+	-	+	+	+	++
Wilsonia backhousei	++	+++	+++	-	+	+

Table II ANOVA for species richness in Jervis Bay

Source	df	MS	F denom.	F	P
Year	1	6.828	Residual	6.26	**
Creek	3	32.58	Plot(C)	3.67	**
Y x C	3	6.70	Y x E	0.74	ns
Elevation	2	386.30	C x E	23.99	***
Y x E	2	2.99	Residual	2.74	ns
C x E	6	16.10	Plot(C)	1.81	ns
Plot(C)	36	8.87	Residual	8.13	***
Residual	330	1.09			

n.s. not significant, ** P < 0.01, *** P < 0.001

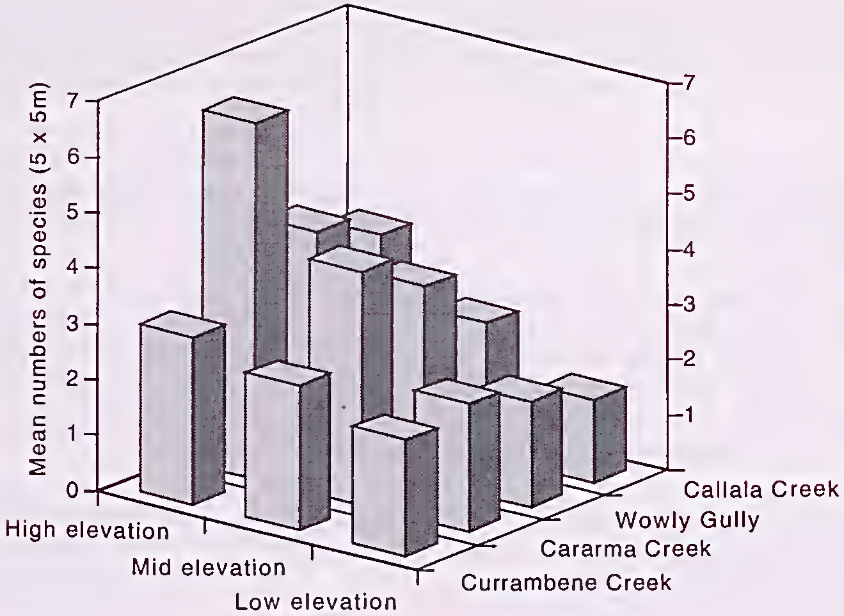


Figure 2. Mean species richness in 5 X 5 m quadrats across four creeks and three elevations in Jervis Bay.

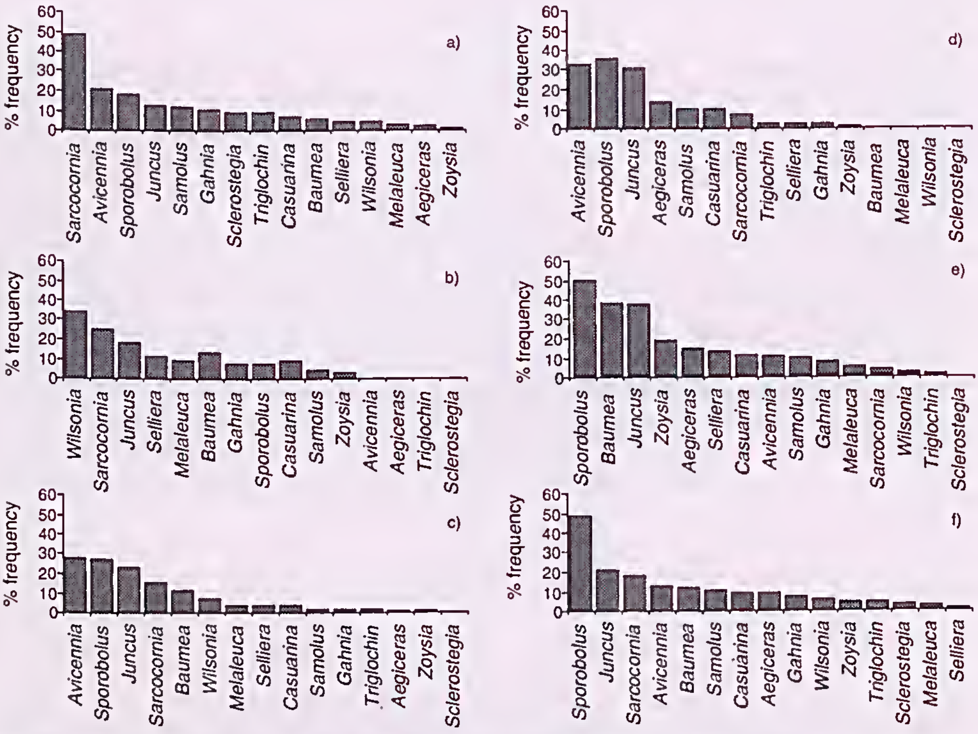


Figure 3. Percent frequency of the 15 most common species found in transects in a) Cararma Creek, b) Wowly Gully, c) Callala Creek, d) Currambene Creek, e) Moona Moona Creek, and f) summed for all creeks sampled in Jervis Bay.

Fine resolution transect data for two transects in each of Cararma Creek and Moona Moona Creek are shown (Figure 4a–d) and indicate the gradational nature of the mangrove–saltmarsh-fringe forest zonation.

Table III Summary ANOVA results for population measures of: D = density, H = height, S = seedlings, St = stems, G = Girth. *Av* = *Avicennia marina, Ae* = *Aegiceras corniculatum, Ca* = *Casuarina glauca, Ga* = *Gahnia filum, Sc* = *Sclerostegia arbuscula,*

Factor	***Av***			***Ae***			***Ca***			***Sc***		***Ga***
	D	H	S	D	H	St	D	H	G	D	H	D
Creek	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	–	–	n.s.
Plot(C)	***	***	n.s.	***	***	*	*	***	*	**	**	***

n.s. not significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Population measures

Two species of mangrove *Avicennia marina* and *Aegiceras corniculatum*, the saltmarsh shrub *Sclerostegia arbuscula* and the tree *Casuarina glauca* could be readily counted and measured as genets. In addition, tussocks of the saltmarsh sedge *Gahnia filum* could be counted. Data from subsets of all plots sampled for *Avicennia, Aegiceras* and *Gahnia* were used in nested analyses of variance designed to compare a range of spatial scales. In most cases significant differences were detected at the smallest spatial scale, i.e. among plots (Table 3).

Avicennia marina

Seedling densities in quadrats range from one to more than 100 plants, with the distribution being skewed toward low densities (Figure 5a). Adult and juvenile densities for the same quadrats ranged from 1–56 plants and were also skewed toward low densities (Figure 5b). The height of adult plants ranged from 50 cm to 8 m, although few plants exceeded 5 m (Figure 5c).

Aegiceras corniculatum

The density of shrubs ranged from 1–60 plants in quadrats, and most had at least two basal stems (Figures 6a). Heights ranged from 20–300 cm, with a predominance of plants in the 60–80 cm size class (Figure 6b).

Casuarina glauca

The density of adult trees ranged from 1–20 plants in quadrats (Figure 7a). Heights ranged from 1–16 m and were approximately normally distributed (Figure 7b). In contrast, basal girth was skewed towards the smaller size classes, ranging from 10–120 cm (Figure 7c).

Sclerostegia arbuscula

The density of shrubs ranged from 1–40 plants in quadrats of (Figure 8a), with heights from 10–120 cm (Figure 8b).

Gahnia filum

The density of tussocks in quadrats ranged from 1–20 and was strongly skewed toward low densities (Figure 9).

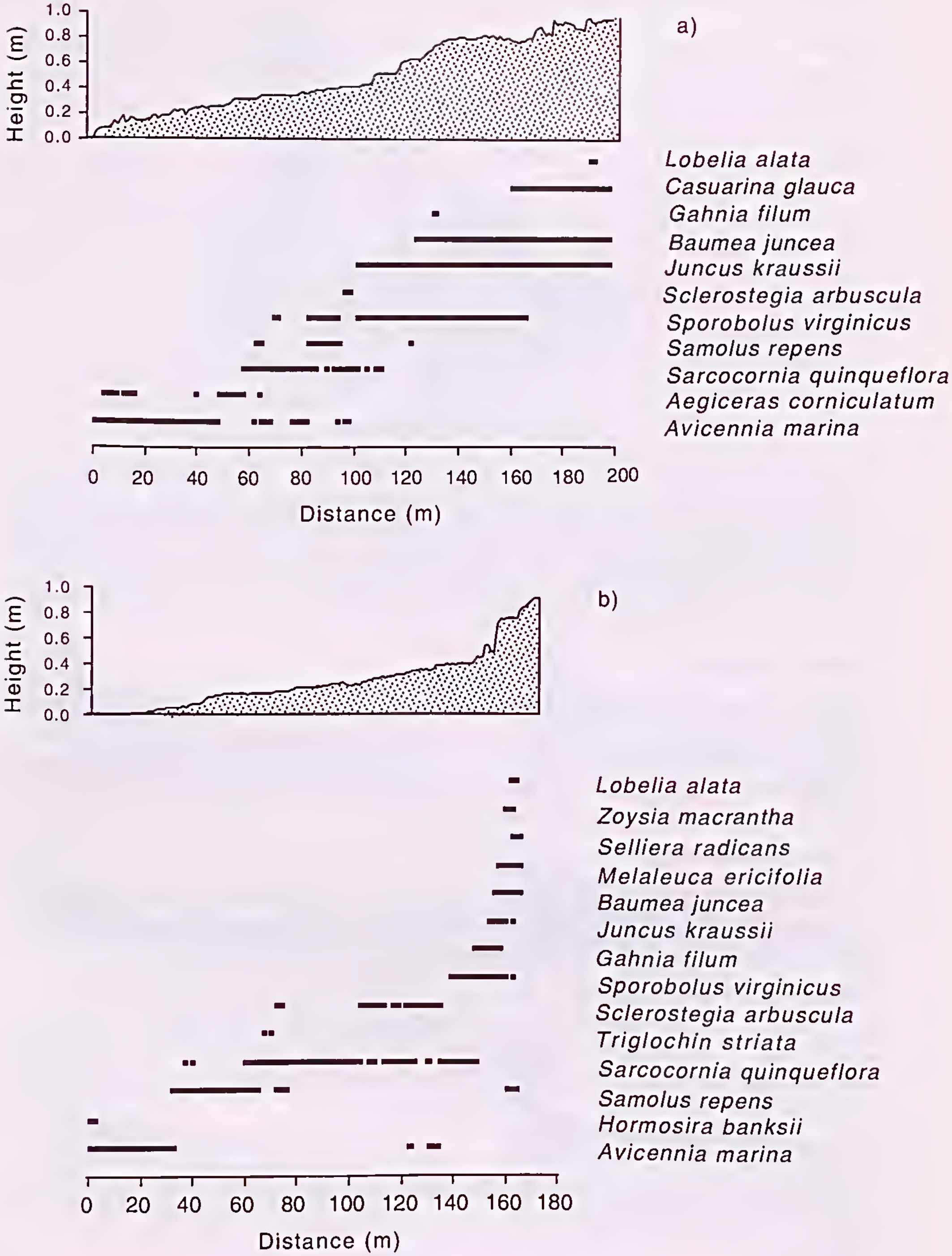
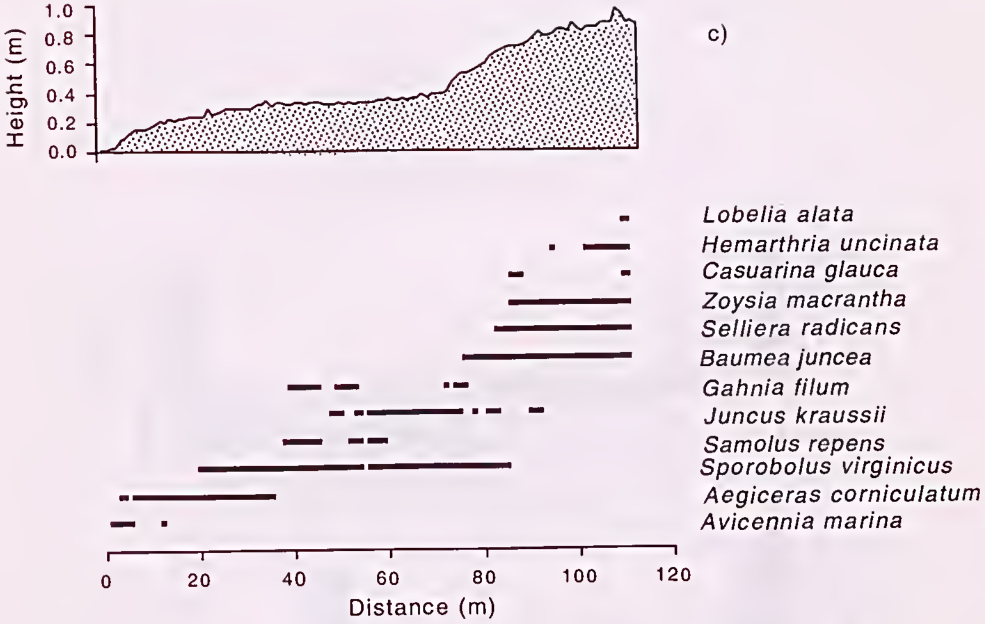
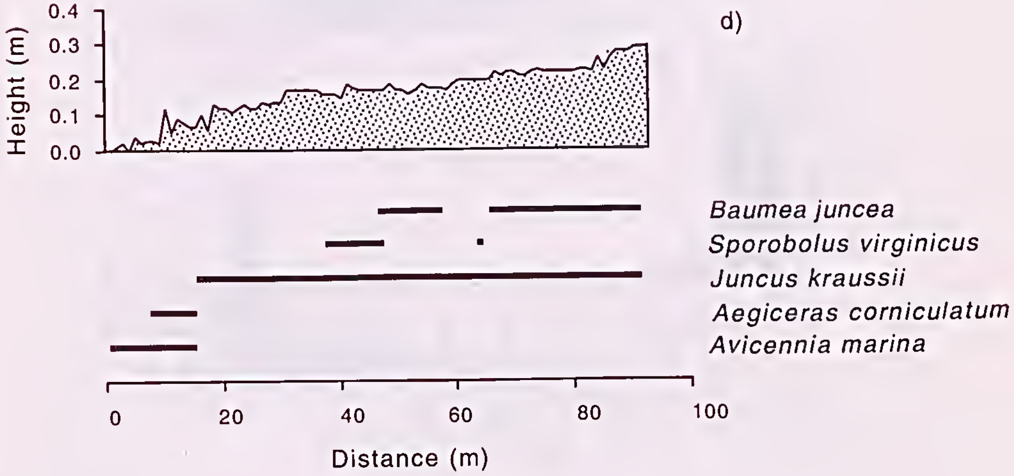


Figure 4. Distribution of plants and height above Australian Height Datum along two transects in Cararma Creek (a, b) and Moona Moona Creek (c, d).


c)
Height (m)
1.0
0.8
0.6
0.4
0.2
0.0
Lobelia alata
Hemarthria uncinata
Casuarina glauca
Zoysia macrantha
Selliera radicans
Baumea juncea
Gahnia filum
Juncus kraussii
Samolus repens
Sporobolus virginicus
Aegiceras corniculatum
Avicennia marina
0
20
40
60
80
100
120
Distance (m)


d)
Height (m)
0.4
0.3
0.2
0.1
0.0
Baumea juncea
Sporobolus virginicus
Juncus kraussii
Aegiceras corniculatum
Avicennia marina
0
20
40
60
80
100
Distance (m)

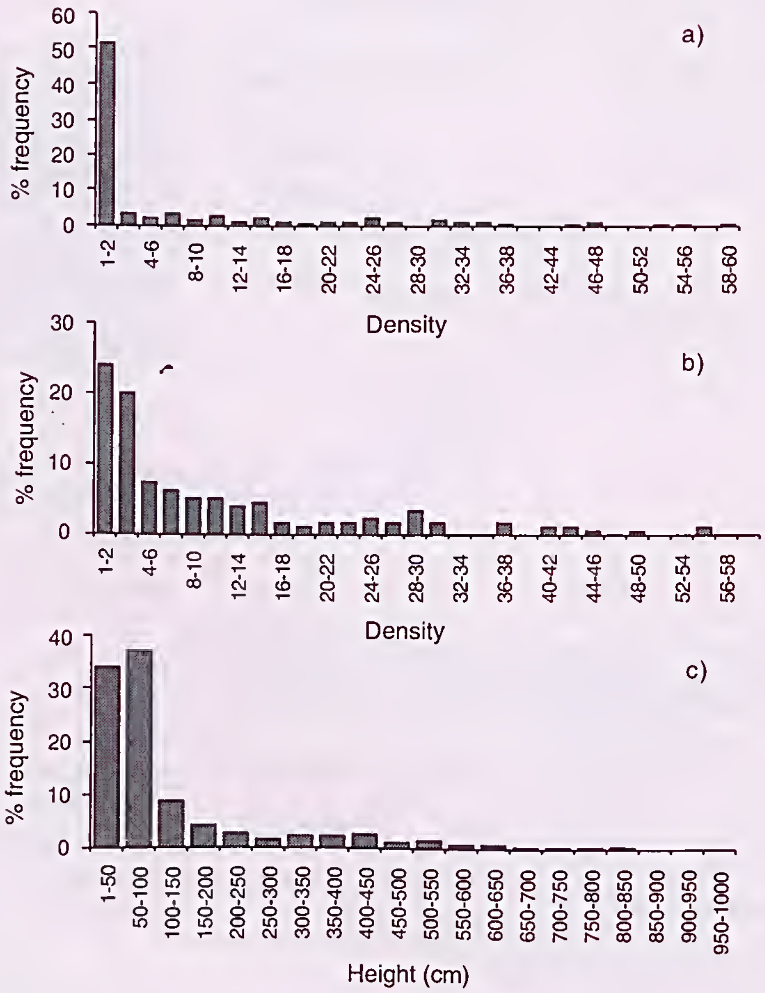


Figure 5. Percent frequency of population measures for *Avicennia marina* a) seedling density (n = 172 quadrats), b) juvenile and adult density (n = 172 quadrats), c) juvenile and adult height classes (n = 1863 stems).

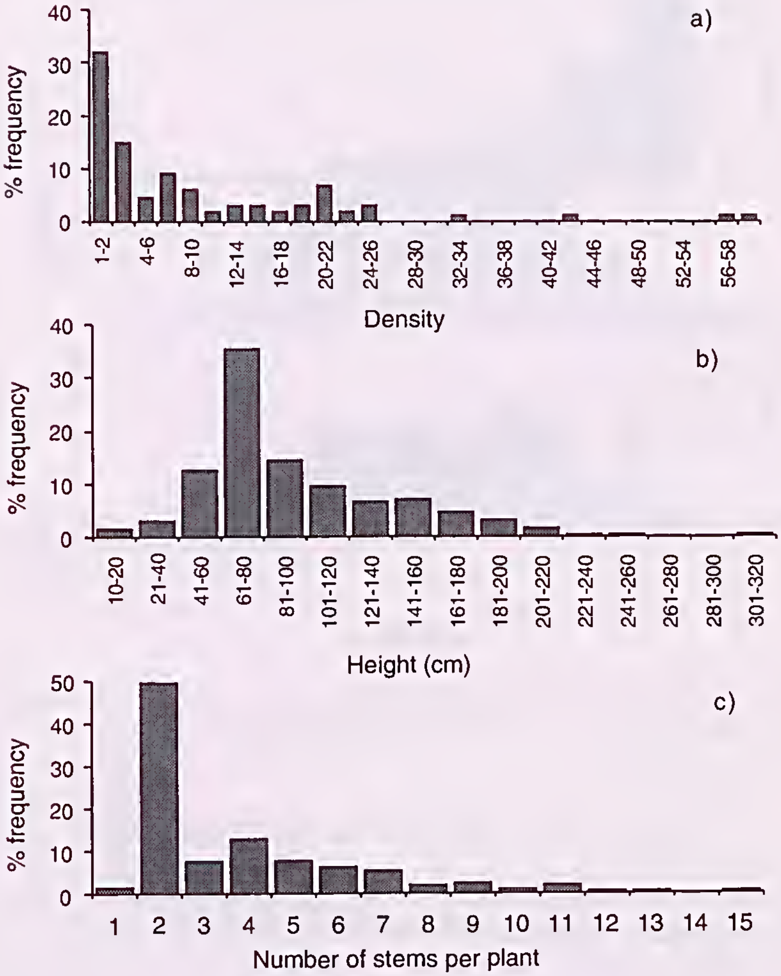


Figure 6. Percent frequency of population measures for *Aegiceras corniculatum* a) adult density (n = 88 quadrats), b) adult height classes (n = 1045 shrubs), c) adult stems per genet (n = 1045 shrubs).

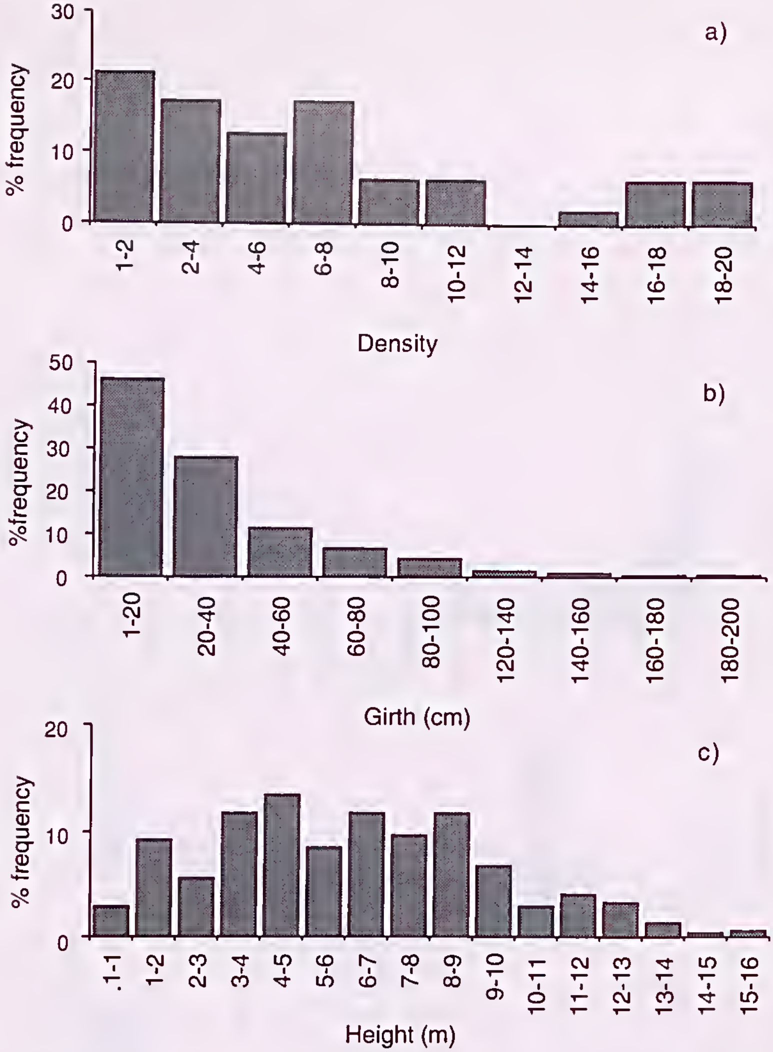


Figure 7. Percent frequency of population measures for *Casuarina glauca* a) adult density (n = 48 quadrats), b) basal girth classes (n = 340 trees), c) height classes (n = 346 trees).

Ordination and classification of plant communities

The ordination of site attributes showed a pattern across two major ordination axes that can be correlated with two broad environmental gradients (Figure 10). Both divisive and agglomerative classification methods produced the same overall pattern of classification although the level at which dendrograms defined similar groups was different. At the finer group level, the agglomerative method produced groups that were intuitively recognisable as patches that could be discerned in the field. Initial analysis erected some 30 groups and these were subsequently fused in 12 complexes (Figure 11), that have the equivalent rank of an association in phytosociology. Smaller sub-groups have the status of a sub-association. A constancy table of the relative

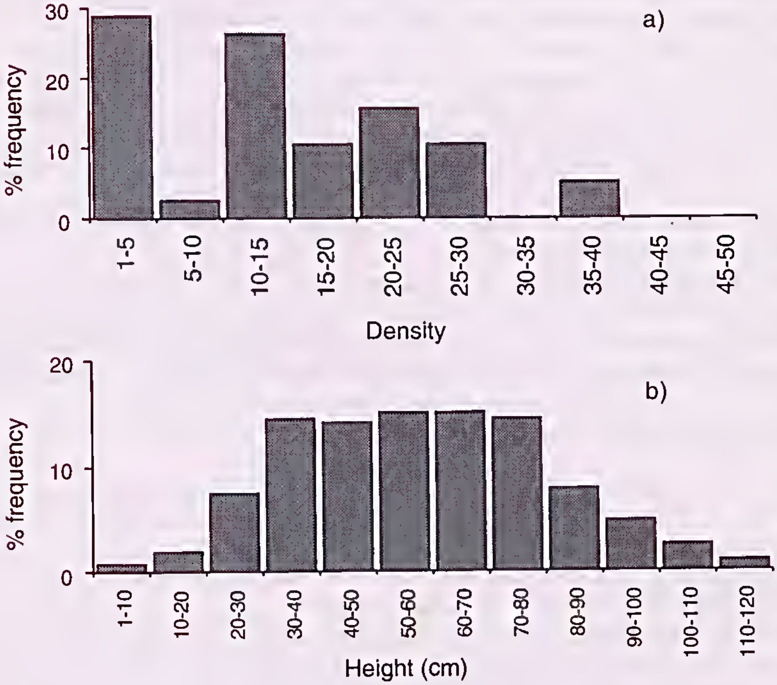


Figure 8. Percent frequency of population measures for *Sclerostegia arbuscula* a) adult density (n = 38 quadrats), b) height classes (n = 509 shrubs).

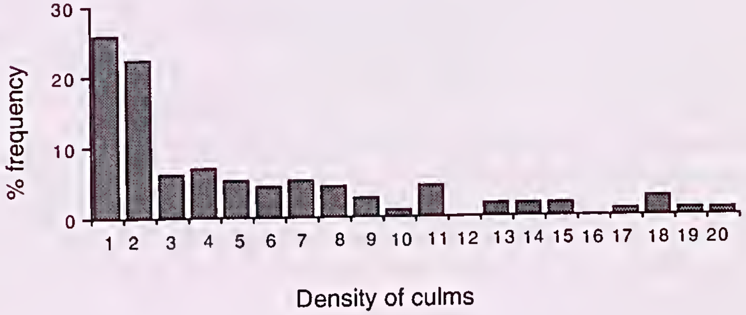


Figure 9. Percent frequency of the density of *Gahnia filum* (n = 116 tussocks).

occurrence of species in complexes and in the sub-groups is shown in Appendix II together with the number of quadrats sampled and species richness in quadrats.

Avicennia complex (A)

The *Avicennia* complex was found in the four major creeks entering the Bay and extended from about Mean Sea Level (MSL) to 50 cm above MSL. Physiognomically, the complex ranged from forests of single-stemmed trees with a closed canopy to low open shrublands. Floristic variation was limited to associated algal species, which were not included in the analysis, and the occasional saltmarsh plant found as a ground cover. Free living (unattached) *Hormosira banksii* commonly occurred as a ground cover in the lower intertidal. Four structural sub-groups have been defined: A1) single-stemmed stands of *Avicennia marina* that formed woodlands or dense thickets where recent accretion had occurred. *Aegiceras corniculatum* often formed a scattered understorey in more open situations; A2) multi-stemmed stands of *Avicennia marina* with occasional canopy gaps were common in most creeks and generally had an abundant seedling understorey; A3) multi-stemmed stands of *Avicennia marina* with open canopies allowed the growth of saltmarsh plants in canopy gaps. The main species were *Sarcocornia quinqueflora, Sporobolus virginicus* and *Samolus repens;* A4) low shrubland of *Avicennia marina,* was usually found behind taller stands on hypersaline flats adjacent to saltmarsh, but it also occurred on rock platforms in sheltered parts of the bay.

Aegiceras complex (B)

Shrublands of *Aegiceras corniculatum* were found at higher elevation toward the back of the *Avicennia* complex in the seaward sections of creeks, although there were also dense thickets along the creek banks in Currambene Creek.

Sclerostegia complex (C)

Open shrublands dominated by *Sclerostegia arbuscula* with an understorey of *Sarcocornia quinqueflora* were found only in Cararma Inlet. Two sub-groups were evident from classification analysis: C1) Bispecific stands of *Sclerostegia* and *Sarcocornia* with the alga *Chaetamorpha capillaris* as a ground cover; C2) *Sclerostegia* and *Sarcocornia* intermingled with *Avicennia* shrublands at lower elevations.

Sarcocornia complex (D)

Extensive herbfields dominated by *Sarcocornia quinqueflora* occurred in most areas and were gradational with several complexes. They commonly occurred at about the 1.4–1.5 m tide level in the saltmarsh although an extensive sward was also found on the southern side of Bowen Island above high water. Two sub-groups could be distinguished in the analysis: D1) monospecific herbfields of *Sarcocornia quinqueflora;* D2) herbfields dominated by *Sarcocornia* associated with *Triglochin striata* which were found in depressions and at the edges of ponds.

Sporobolus complex (E)

Grasslands forming the *Sporobolus* complex were generally found on well-drained soils in the saltmarsh. This vegetation was also found along the southern cliff tops of Bowen Island. Two sub-groups were distinguished: E1) monospecific grasslands of *Sporobolus virginicus* of variable cover; E2) mixed grasslands of *Sporobolus* and *Sarcocornia.*

Samolus complex (F)

Herbfields dominated by *Samolus repens* were mainly found in the lower saltmarsh where they were often shaded by mangroves. Two sub-groups were described on the basis of field observations: F1) monospecific patches of *Samolus* were found in shady areas adjacent to mangrove open woodland and were often extensive enough to be mapped; F2) mixed areas of *Samolus*, *Sarcocornia* and *Sporobolus* that intergraded with the *Sarcocornia* complex.

Wilsonia complex (G)

Saltmarsh with a constant presence of *Wilsonia backhousei* formed extensive areas in Wowly Gully and in Callala Creek at about the level of spring tides. *Wilsonia* was also occasionally found on sheltered rock platforms at Cabbage Tree Point. Four sub-groups in the complex could be distinguished: G1) monospecific herbfields of *Wilsonia backhousei*; G2) bispecific areas with *Wilsonia* and *Sarcocornia*; G3) mixed herbfields with *Sarcocornia*, *Triglochin* and *Juncus*; G4) mixed tussocky herbfields with *Gahnia filum* in the upper marsh.

Juncus complex (H)

Rushlands dominated by *Juncus kraussii* were typical of the upper saltmarsh in most localities. Considerable floristic variation occurred within the complex, and three sub-groups were described: H1) dense monospecific stands that were typical of the saltmarsh adjacent to the mangroves in the upper ends of creeks with freshwater runoff; H2) mixed rushlands of *Juncus* and *Sporobolus* which were widespread and occasionally contained scattered shrubs of *Aegiceras*; H3) more diverse areas of mixed *Juncus*, *Sporobolus*, *Gahnia* and *Baumea* which were typically found in the upper ends of smaller creeks.

Baumea complex (I)

Sedgelands dominated by *Baumea juncea* occurred in the upper marsh under the influence of freshwater creeks and groundwater. This complex was transitional between the saltmarsh and fringing forests in some locations. Two sub-groups were described from field observations and classification: I1) monospecific patches of *Baumea juncea*; I2) sedgelands of mixed *Baumea juncea* and *Juncus kraussii*.

Gahnia complex (J)

Tussocky sedgelands dominated by *Gahnia filum* and a ground cover of *Sporobolus* commonly occurred in the transition zone between the saltmarshes and the fringe forests. Three sub-groups of sedgeland were defined: J1) mixed stands with *Sarcocornia* and *Samolus*; J2) mixed stands with *Sarcocornia* and *Juncus*; J3) mixed stands with the tussock grass *Stipa stipoides*, which had a restricted distribution to sandy banks.

Casuarina complex (K)

The swamp oak, *Casuarina glauca*, formed extensive fringe woodlands behind saltmarshes in most localites. Fringe forests were defined as areas that were influenced by saline, waterlogged soils but were dominated by trees other than mangroves. Classification analysis indicated that this complex has close affinities with the saltmarsh and the species, like mangroves, graded from one type to the next. Four woodland sub-groups could be distinguished: K1) *Casuarina* woodlands with an understorey dominated by *Selliera radicans* were mainly found in basin areas; K2) woodlands similar to those described above but with a shrubby understorey of *Myoporum acuminatum* were restricted to Cararma Creek; K3) *Casuarina* woodlands with an understorey of *Sporobolus virginicus* were more common along freshwater creeks ; K4) *Casuarina* woodlands with an understorey of *Sporobolus virginicus*, *Zoysia macrantha* and the rush *Juncus kraussii* were also commonly found where there was ground water runoff.

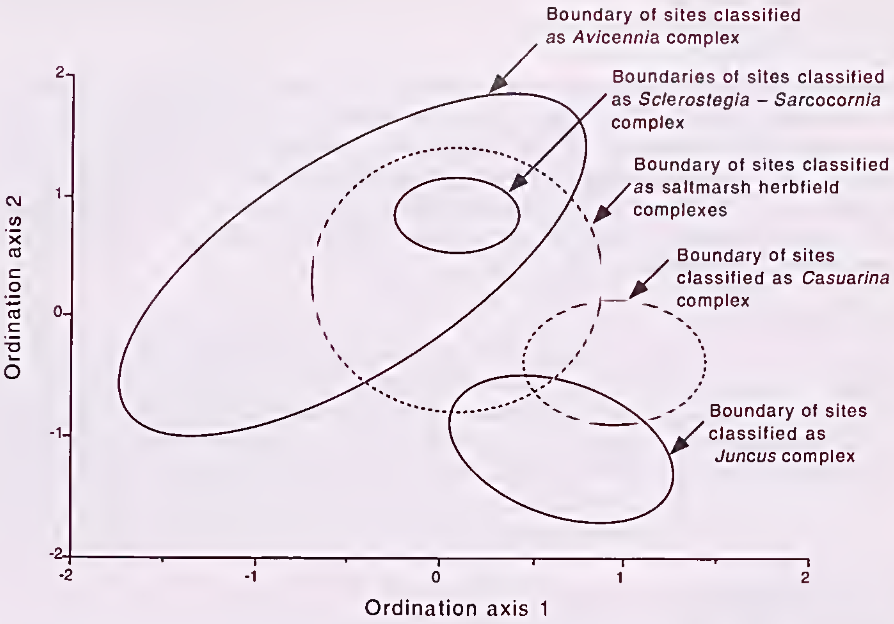


Figure 10 Ordination (hybrid multidimensional scaling) of quadrats simplified to two vectors. Boundaries of major classification groups shown.

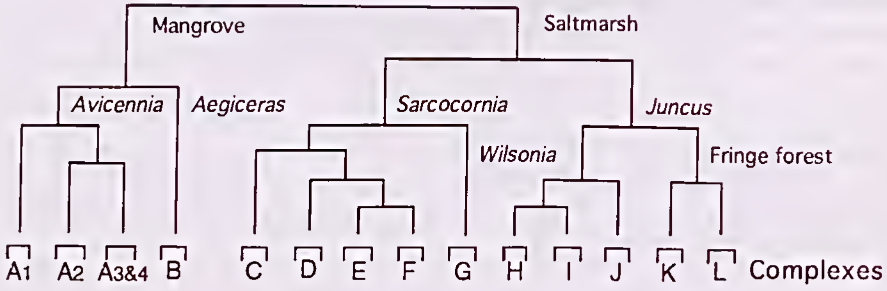


Figure 11 Classification (agglomerative) to the 12 group association level based on vascular plant species and mangrove pseudospecies. Letters correspond to associations described in the text.

Melaleuca complex (L)

Fringing thickets of the shrub *Melaleuca ericifolia* occurred on sandy sediments with some saline influence. Two floristic sub-groups could be distinguished from the analysis although they were mapped as a single complex: L1) thickets of *Melaleuca* occurred as an understorey of *Casuarina glauca* with a ground cover of *Baumea juncea, Lobelia alata* and *Hemarthria uncinata*; L2) thickets of *Melaleuca* also occurred as shrublands and graded into *Eucalyptus botryoides* woodland.

Other complexes

Several other complexes also occurred in areas that were infrequently inundated with saline water. However, they were not sampled so the structure and dominant species are only briefly described.

Reedswamps of *Phragmites australis* were common in Currambene Creek, while areas of swamp forest dominated by *Eucalyptus robusta* occurred adjacent to, and graded into, the *Casuarina glauca* forests. Sedgelands of *Cyperus laevigatus* were also found in the shallow, brackish creeks and lagoons at the backs of the beaches that fringe the Bay. The ephemeral and semi-permanent ponds of Cararma Creek supported an unusual submergent, macrophyte vegetation of *Ruppia* and the charophyte *Lamprothamnion. Mimulus repens* often colonised the edges of the ponds when they dried out.

Discussion

Species composition and distribution

About 140 species of vascular plants (native and exotic) were found in the mangroves, saltmarsh and fringe forests Jervis Bay. This is approximately half of the recorded flora for saltmarshes in New South Wales (Adam *et al.* 1988). Previous studies of saltmarshes at Lake Illawarra found 127 species (Yassini 1985), while Anderson *et al.* (1981) found 119 species in peripheral vegetation at eight estuaries adjacent to Jervis Bay.

Previous studies have indicated that Jervis Bay contains a number of species that are at their biogeographic limits and, therefore, are of conservation significance (Adam and Hutchings 1987). Several species are at their northern limits in Jervis Bay or have larger populations in Jervis Bay than elsewhere (Table 1). However, the status of saltmarsh plants in NSW is poorly understood and requires further study before conclusions can be made about rarity.

Species richness varied over several spatial scales, but more species were found in the upper saltmarsh than at lower elevations. Differences among creeks were also found; in particular Cararma Creek had consistently higher species numbers in quadrats than other creeks. This may be due the heterogenous physiography of the creek and the relatively undisturbed catchment. Differences in species richness were also detected in time; this was surprising given that all the species were long-lived. On close examination these difference were very small and simply reflect the ability of the sampling design to resolve small differences.

One of the pitfalls in using species richness as a general measure of assemblage trends is that species composition may change without affecting richness. Thus, exotic species could displace existing species, and the richness measure alone would not detect this. New methods using similarity measures to assess changes in diversity are currently being developed to address this problem.

Population measures

The density of *Avicennia marina* was highly variable in Jervis Bay at small spatial scales ranging from less than 100 plants ha^{-1} to 20000 plants ha^{-1}. This range of density is not unusual, as similar variability has been found in Moreton Bay (Dowling 1986) and in other estuaries in south-eastern Australia (Clarke unpub.). Differences in mean density, height and basal girth between plots, (0.1 ha) reflect a high degree of spatial heterogeneity and highlight the difficulty in generalising for creek and bay spatial scales.

Densities of *Aegiceras corniculatum* showed a similar range to that of *Avicennia marina*, although a larger proportion of the population was found in denser patches. Higher densities and taller shrubs than those in Jervis Bay have been reported in Moreton Bay (Dowling 1986). The height of juvenile and adult *Aegiceras corniculatum* ranged from 10 to 350 cm in Jervis Bay, with most plants being between 60 and 80 cm tall. More than 95% of plants measured were multi-stemmed, and the range of variation appears to be the same at all locations. The low stature of *Aegiceras* in Jervis Bay make this species particularly susceptible to hydrocarbon pollutants because photosynthetic surfaces would be exposed. Recovery after such disturbances may be slow as few propagules appear to establish (as noted by Dowling (1986) in Moreton Bay).

Sclerostegia arbuscula has been found in only eight estuaries in southern New South Wales and the population at Cararma Inlet is the most northern and possibly the largest. Densities of *Sclerostegia* in Cararma Creek were highly variable and the average height of the shrubs (60 cm) appears to be less than that found at more temperate latitudes. No seedlings or juvenile plants were seen, although flowers were recorded each year in autumn. Scorching by fire appeared to have killed plants near the edge of the saltmarsh and plants were easily damaged by trampling. However, examination of aerial photographs suggested that the overall populations in Cararma Inlet have been stable since 1944.

Densities of *Casuarina glauca* ranged from 400 to 8000 plants ha^{-1}, and density distributions were less skewed toward low densities than the densities of either *Avicennia* or *Aegiceras* . The ranges of densities and heights of trees appeared to be similar in all locations. Very few seedlings and juvenile plants were found. Observations at Callala Creek and Moona Moona Creek suggested that fire will kill trees if their crowns are scorched, although partially scorched trees appeared to resprout from the base of the stem.

Vegetation ordination and classification

Both direct and indirect gradient analyses clearly showed that mangrove, saltmarsh and peripheral vegetation form continua when sampled and analysed in an unbiased way. The underlying environmental variables that correlated intuitively with these gradients appeared to be elevation and variability in moisture content, although the causal factors controlling the distribution of species are likely to be much more complex. When site classification was superimposed on the ordination, some broad clusters were discernible but smaller units of classification were poorly resolved. This indicated that the ecological variables influencing such patterns are more complex than a simple two dimentional model.

While site ordination showed the gradational nature of the vegetation, the classification of vegetation types was required for description and comparison among other areas of saltmarsh. A critical decision in the process was to select the level in hierarchical classifications at which vegetation units were described. In this study the 30 group level was initially selected and this was fused into 12 units based on subjective judgement and interpretation of ordination diagrams.

The mangrove complexes described in this study have the same floristic composition as the southern Australian associations described by Bridgewater (1989). However, sub-groups are not directly comparable with Bridgewater's because pseudospecies were used in the Jervis Bay study. Outhred and Buckney (1983) used a similar approach in the Hunter estuary but their pseudospecies were based on vigour rather than form. The distribution of *Avicennia* forms seemed to be correlated with sedimentation and salinity: taller, single-stemmed *Avicennia* stands grew on newly accreted substrates, while multi-stemmed trees were found on older sediments. In saltmarshes, *Avicennia* was shorter and stunted, which is interpreted as the influence of higher salinity (Davie 1984). Elsewhere on the south coast of NSW, grazing by cattle can reduce the stature of *Avicennia*. *Aegiceras* shrublands were found at the rear of *Avicennia* at the entrance to the bay in Cararma Inlet and Currambene Creek. In contrast *Aegiceras* fringed the creek banks in the more brackish sections of creeks. This pattern may be related to patterns of propagule dispersal rather than a growth response to salinity (Clarke and Myerscough 1991).

Of the 25 saltmarsh communities described by Adam *et al.* (1988), about 16 are analogous to complexes found in Jervis Bay during the present study. However, many of the sub-groups in this study, which have equivalent rank to the sub-association of Adam *et al.* (1988) and Bridgewater (1982), have not been described previously. This is not surprising given the lack of information concerning saltmarshes in NSW. The distribution of saltmarsh complexes is thought to be related to the influence of topography on salinity and drainage (Adam *et al.* 1988). This probably gave rise to the zonal patterns seen in Jervis Bay, although such patterns were rarely consistent within or between creeks. Mosaic patterns were also common in areas with cryptic topography and drainage, and these patterns may also have been influenced by interspecific interactions or the actions of fires and herbivores.

The fringing vegetation of saltmarsh in southern Australia has not been fully described or classified. The ground cover beneath the *Casuarina* woodlands and *Melaleuca* thickets in Jervis Bay often consisted of saltmarsh plants. This was particularly evident in the upper sections of Cararma Inlet where mangroves were intermingled with *Casuarina* and *Myoporum*. The boundaries between freshwater wetland and saltmarsh also became diffuse in the upper reaches of some tidal inlets and swamp woodlands the ground cover often contained saltmarsh species.

Conservation

The total area of 'saltmarsh' and 'mangrove' in NSW is estimated to be less than 57 km^2 and 108 km^2 respectively (West *et al.* 1985). Consequently, these vegetation formations are of high conservation significance in NSW because of their small area and distribution. Existing conservation reserves in New South Wales of mangrove, saltmarsh, and their associated fringe forests may not adequately protect all assemblage types because the range of variation within the broad terms 'mangrove', 'saltmarsh' or 'fringe forest' has not been adequately documented. Similarly, comprehensive information about species distribution and abundance is lacking and therefore their conservation status is difficult to assess. Detailed studies, such as the Jervis Bay study and those of Adam *et al.* (1988), begin to address these inadequacies.

Jervis Bay contains extensive areas of relatively undisturbed mangrove and saltmarsh vegetation in catchments that have not been severely degraded by urban development and agriculture. These wetlands also contain a number of species and vegetation types that are apparently rare or absent from other saltmarshes in southern NSW. Added to this biogeographic significance is their importance as a reference system against which future changes can be measured and against which other areas can be compared. The latter, of course, will depend on the preservation of existing wetlands and their catchments. Current zoning as State Environmental Planning Policy 14 Wetlands has, in part, restricted the development of mangroves and saltmarsh wetlands. However, long-term conservation will not be assured until formal conservation reserves are declared and appropriately managed.

Acknowledgments

Mark Fisher, Lani Retter and Gavin Tinning helped with various aspects of the field work and analysis of data. Paul Adam, Charles Jacoby, Peter Myerscough and Trevor Ward provided welcome comments on the manuscipt. The Department of Defence supported studies at Jervis Bay as a part of the CSIRO Baseline Studies of Jervis Bay.

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APPENDIX 1 Vascular plant species list for the littoral habitats of Jervis Bay. * introduced species

DICOTYLEDONS

Aizoaceae
Carpobrotus glaucescens
Disphyma crassifolium
Tetragonia tetragoniodes

Apiaceae
Apium prostratum
Centella asiatica
*Hydrocotyle bonariensis**
Hydrocotyle acutiloba

Apocyanaceae
Parsonsia straminea

Asteraceae
*Aster subulatus**
Brachyscome graminea
Centipeda minima
*Chrysanthemoides monilifera**
*Conyza albida**
Cotula coronopifolia
Leptinella longipes
Eclipta platyglossa
Epaltes australis
Ozothamnus diosmifolius
*Hypochaeris radicata**
Olearia viscidula
Pseudognaphalium luteoalbum
Senecio hispidulus
Senecio lautus
Senecio linearifolius
*Senecio madagascariensis**
Senecio minimus
*Sonchus asper**
*Sonchus oleraceus**
*Taraxacum officinale**

Avicenniaceae
Avicennia marina

Brassicaceae
*Cakile maritima**

Campanulaceae
Wahlenbergia gracilis

Caryophyllaceae
Spergularia sp.B
*Spergularia rubra**
Stelleria flaccida

Casuarinaceae
Casuarina glauca

Chenopodiaceae
Atriplex australasica
Atriplex cinerea
Chenopodium glaucum
Einadia hastata
Rhagodia candolleana

Chenopodiaceae (cont'd)
Sarcocornia quinqueflora
Sclerostegia arbuscula
Suaeda australis

Convolvulaceae
Calystegia soldanella
Cuscuta tasmanica
Dichondra repens
*Ipomea cairica**
Wilsonia backhousei
Wilsonia rotundifolia

Euphorbiaceae
Poranthera microphylla

Epacridaceae
Monotoca elliptica

Fabaceae
Viminaria juncea
Pultenaea dentata

Gentianaceae
Centaurium spicatum

Geraniaceae
Geranium sp.
Pelargonium australe

Goodeniaceae
Goodenia heterophylla
Goodenia ovata
Selliera radicans

Haloragiaceae
Gonocarpus micranthus

Lauraceae
Cassytha pubescens

Lobeliaceae
Lobelia alata

Loranthaceae
Amyema cambagei

Lyrthaceae
Lythrum hyssopifolia

Fabaceae
Acacia longifolia
Acacia Isophorae

Menyanthanceae
Villarsia exaltata

Myoporaceae
Myoporum acuminatum
Myoporum boninense ssp. australe

Myrsinaceae
Aegiceras corniculatum

Myrtaceae
Acmena smithii
Eucalyptus robusta
Eucalyptus sp. aff. *longifolia*
Eucalyptus tereticornis
Leptospermum juniperinum
Melaleuca ericifolia
Melaleuca squarrosa
Melaleuca styphelioides

Oxalidaceae
Oxalis corniculata

Pittosporaceae
Billardiera scandens
Pittosporum undulatum

Plantaginaceae
Plantago coronopus

Plumbaginaceae
Limonium australe

Primulaceae
Samolus repens

Proteaceae
Banksia ericifolia

Ranunculaceae
Ranunculus inundatus

Rubiaceae
Opercularia aspera

Polygonaceae
Rumex sp.

Scrophulariaceae
Mimulus repens

Solanaceae
Solanum pungetium

Stackhousiaceae
Stackhousia spathulata

Violaceae
Viola hederacea

MONOCOTYLEDONS

Amaryllidaceae
Crinum pedunculatum

Cyperaceae
Baumea juncea
Carex appressa
Carex pumila
Cyperus laevigatus
*Cyperus polystachyos**
Gahnia filum
Gahnia sieberiana
Isolepis cernua

Cyperaceae (cont'd)
Isolepis inundata
Isolepis nodosa
Schoenoplectus validus
Schoenoplectus litoralis

Hydrocharitaceae
Halophila decipiens?
Halophila ovalis

Iridaceae
*Gladiolus gueinzii**

Juncaceae
*Juncus articulatus**
Juncus kraussii

Lomandraceae
Lomandra longifolia

Juncaginaceae
Triglochin procera
Triglochin striata

Orchidaceae
Dendrobium linguiforme
Dendrobium teretifolium

Poaceae
Agrostis billardieri
*Ammophila arenaria**
Cynodon dactylon
Danthonia linkii var linkii
Danthonia setacea
Distichlis distichophylla
Deyeuxia quadriseta
Festuca littoralis
Hemarthria uncinata
Imperata cylindrica
Paspalum vaginatum
Phragmites australis
*Parapholis incurva**
Poa labillardieri
*Polypogon monspeliensis**
*Spartina anglica**
Spinifex sericeus
Sporobolus virginicus
*Stenotaphrum secundatum**
Stipa stipoides
Themeda australis
Zoysia macrantha

Posidoniaceae
Posidonia australis

Restionaceae
Leptocarpus tenax

Ruppiaceae
Ruppia maritima

Zosteraceae
Heterozostera tasmanica
Zostera capricorni/muelleri?

APPENDIX II Major species components of vegetation types as classified using TWINSPAN. Species composition given as relative frequency in classified groups; + = < 10%, I = 11–20%, II = 21–40%, III = 41–60%, V = 81–100%

Vegetation complex	**A**				**B**	**C**		**D**		**E**		**F**		**G**				**H**			**I**		**J**			**K**				**L**
Vegetation sub-groups	**A1**	**A2**	**A3**	**A4**	**B1**	**C1**	**C2**	**D1**	**D2**	**E1**	**E2**	**F1**	**F2**	**G1**	**G2**	**G3**	**G4**	**H1**	**H2**	**H3**	**I1**	**I2**	**J1**	**J2**	**J3**	**K1**	**K2**	**K3**	K4	L1
Number of quadrats	16	15	10	62	57	24	8	8	11	7	4	-	8	-	7	10	8	5	39	12	-	6	13	13	5	16	4	9	12	10
Total 'species' number	3	4	6	7	8	10	9	2	7	7	5	1	7	1	2	6	11	3	11	15	1	5	11	12	7	22	11	8	21	25
Mean 'species' number	2	2	2	2	3	3	5	1	2	3	3	1	4	1	2	4	5	1	3	5	1	3	5	5	5	7	8	3	7	8
Main species																														
Avicennia seedlings	IV	V	IV	IV	I																									
Avicennia single-stemed trees	V	+																												
Avicennia multi-stemed trees		V	+	+	+																									
Avicennia tall shrubs	II		+	II																										
Avicennia short shrubs			V	V		I	V			III			II																	
Aegiceras corniculata	I	+		I	V					+			II						+	+										
Sarcocornia quinqueflora			V	+		V	V	V	V	V	IV		V		V	V	II		+				V	IV		III	+			
Sclerostegia arbuscula						V	V		+	+																				
Sporobolus virginicus			I			+	+	+	+	V	V		V				III		V	V		V	V	V	IV	IV	+	V	IV	
Triglochin striata						+	+		V		+					III			+				II			+				
Chaetomorpha spp.						I	I																I	II						
Suaeda australis				+		+	+			+														I		+	+	+	+	
Samolus repens						+	+		+		III	V	V				+		I	II		+	III	II	III	II	IV		III	III
Wilsonia backhousei									+					V	V	V	V		+						+	+			+	
Gahnia filum						I	I		+				+				V		I	V			V	V	V	I	IV		+	+
Juncus kraussii										+						IV	II	V				V	+	V	III	V	V	II	V	I
Baumea juncea																	II	+		V	V	V	+	II	III	I	III		V	V
Stipa stipoides																		+		+					V					
Selliera radicans						+											III			+			+	III	II	V	V	III	III	III
Dendrobium teretifolium																										+		+	II	
Casuarina glauca																	+		+	+			III	II		V	V	V	V	V
Myoporum accuminatum																											V			
Zoysia macrantha																	+			+						+			III	II
Tetragona tetragoniodes																			+									+		
Senecio linearifolia																														II
Aster subulatus																				+						+			+	II
Phragmites australis													+						I	+								+		
Melaleuca ericifolia																	I			+									+	V
Lobelia alata																	+			+			+	+					III	V
Viola hederacea																										+				+
Apium australe																							+	+		+				
Hemarthria uncinata																				+										III
Chenopodium glaucum																						+								I
Goodenia ovata																										+	+			+
Cassytha pubescens																														+
Lamprothamnium papulosum																							+							
Spergularia sp.																														
Isolepis cernua																I														
Cynodon dactylon																													+	
Parapholis incurvata																+														
Leptinella longipes																										+				
Cotula coronipifolia																										+				
Crysanthemoides moniliferum																												+	I	

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REVIEW

Vegetation survey and mapping in Queensland

V.J. Neldner, Queensland Botany Bulletin No. 10, Brisbane: Queensland Department of Primary industries, 1993, 70 pp.

This is a timely review on the history and current status of vegetation survey and mapping in Australia. It draws on a wide body of literature in examining past and present approaches to vegetation survey and mapping with particular emphasis on the work undertaken by the Queensland Herbarium.

The report summarises the history of plant community classification, sampling methods used to classify vegetation, values and uses of vegetation surveys, limitations of surveys, the problem of mapping scale and future directions including the use of geographical information system (GIS) technology. Many tables complement the text.

The imposition of classification on the complex world of species distributions results in compromise. This compromise was recognised by early workers in this field and is noted in Neldner's paper by way of a quote from a pioneering doctrine on plant community classification by Beadle and Costin (1952):

"Classification is essentially a compromise between the desire to preserve the natural groupings as continuously varying entities and the need to subdivide them for more utilitarian purposes."

This raises the question — what is the appropriate level of homogeneity of species composition to define communities? This is a key question still requiring more research. Yet it is crucial in the reasoning for examining and defining patterns in nature. Scale or intensity of survey relates to this. As Neldner illustrates, with the history of Queensland vegetation mapping, scale has been chosen largely on the basis of available resources. So 1:1 000 000 and 1:250 000 scales have been adopted for most standard mapping except in special circumstances. The principal aim has been to provide an overview. In NSW we are generally mapping at 1:100 000 scale in the east but 1:250 000 scale in the floristically simpler inland areas. Larger scale maps have been produced for reserves or forests. Given current resources committed to regional botanical survey and mapping in Australia, it will be a very long time before the continent is mapped at say the 1:100 000 scale, yet in my experience this is the minimum scale that land use agencies would like to assist them with property, catchment or reserve management. Other agencies would prefer 1:25 000 mapping for particular areas, for example national parks or state forests.

Lengthy discussion is given to fitting data to the different structural/floristic classifications used in Australia. Perhaps an emphasis should be placed on the need to collect and store raw core attribute data so that it can be used by a range of analyses (Bolton 1992).

Neldner makes an observation that numerical floristic classifications are rarely mapped. What we mainly see on vegetation maps are aerial photograph interpretations of vegetation structure with some dominant floristics applied in some cases (largely depending on the quality and scale of the photographs). Several floristic classifications (whether numerical or traditional) may fall under each photo unit and are described in the text of an accompanying paper. With the advent of more sophisticated modelling, predictive maps may become more important in the future but the quantity of data needed to ensure models work may be so great that the costs of acquiring it may prohibit the project being started or finished. Herein lies a dilemma for the plant ecologist – for a given cost you have the option of acquiring much data over a small area or less data over a larger area. Generally this is solved by relating projects to their purpose and taking into account resources available.

The advent of improved LANDSAT TM imagery with finer levels of resolution has provided an alternative means of coarse scale mapping of less complicated vegetation. This is not successful in complex eucalypt forests on the east coast or tablelands where problems of shadow are encountered and the difference in reflectance of different types of eucalypt forest are small. At this stage LANDSAT cannot replace aerial photographs for vegetation mapping work except for delineating the outer boundaries of forested lands. Such data can be very useful for assisting with ground survey design.

In his discussion on sampling, Neldner could have enlarged on the efficiency of using explicit, well designed, stratified sampling procedures. It has long been appreciated that maximising the number of sampling sites in botanical surveys facilitates better use of exploratory statistical analyses to aid the ecologist in interpreting patterns and query possible determinants of those patterns (for example, McKenzie *et al* (1991).

The problem of dissemination of information is also raised in the report. It pays tribute to this journal for filling a niche by publishing results of vegetation survey and mapping. However, there have been cases in NSW where other Government agencies were unaware of publications relevant to their survey programmes. In some cases this has resulted in duplication of work. With the distribution of index data bases, such as the one being developed for vegetation studies in the Murray Darling Basin, duplication will be minimised in the future.

Another important point canvassed in the report is the possible misuse of digitised vegetation maps or survey data where a third party, who, without the benefit of field knowledge, attempts to draw definitive conclusions from some other person's data. It is likely that this problem will grow with the wider use of GIS. The report rightly raises some fundamental questions for the future, particularly the impact of GIS on vegetation sampling and mapping.

If regional vegetation surveys and mapping have benefits to the tune of 40:1, as suggested by Neldner, it would seem prudent to conduct more surveys throughout Australia. I disagree, however, with the Queensland Herbarium's policy of mapping original vegetation. In NSW we are now concentrating on surveying and mapping existing vegetation cover. Extrapolations to cleared land can be made if observational data is available or modelling is possible but this is seen as a secondary objective.

If carried out under well designed methods, vegetation survey and mapping can form one of the best information bases to assist with the long term management of species and ecosystems and with the rehabilitation of land. There is an urgent need for programs to be accelerated by governments throughout Australia.

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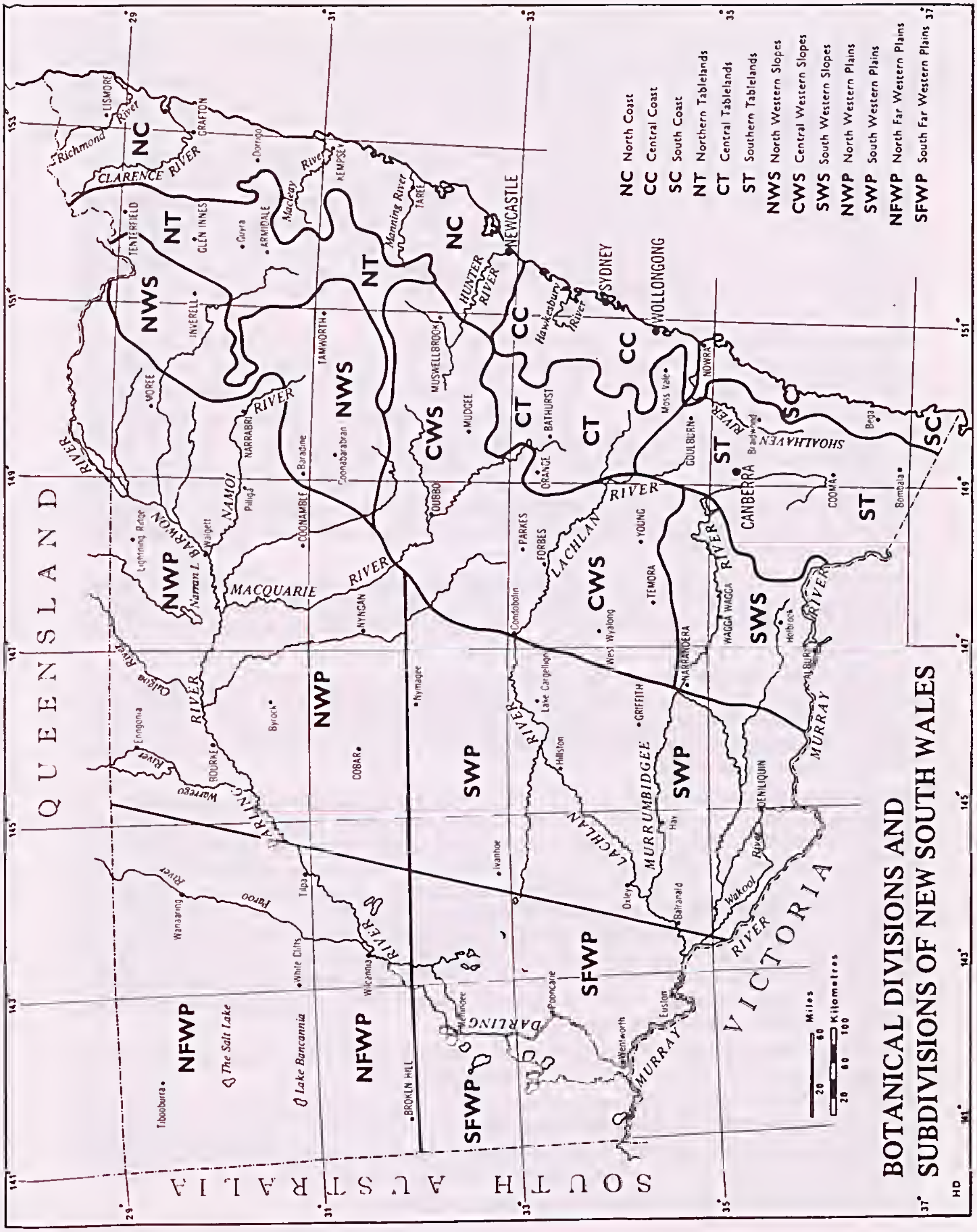


For explanation and description of the Botanical Divisions and Subdivisions of New South Wales see Anderson, R. H. (1961). Introduction. *Contr. New South Wales Natl. Herb. Fl. New South Wales* Nos 1–18, pp. 1–15.

INFORMATION FOR AUTHORS

Cunninghamia is published annually in July. Papers dealing with all aspects of plant ecology, in particular vegetation mapping and plant community dynamics are welcome to be considered for publication. Papers dealing primarily with New South Wales or with comparative data from New South Wales and neighbouring states will be given preference. Brief papers may be published as Short Communications (see previous issues for format).

The deadline for the submission of papers is **1 October** for publication in the following year. Authors are expected to have had their papers peer-reviewed before submission. All papers will be refereed. Two copies of the manuscript should be submitted along with originals of photographs and clear photocopies of all other figures. The full postal address (plus telephone and fax numbers) of the author who will check the proofs and receive correspondence should be included. Once a paper has been accepted for publication the author should provide the paper on a computer disk along with the final artwork for figures etc. The disk should be in IBM compatible (MS-DOS) or Macintosh format and clearly labelled with the word processing program used and the file name(s).

Organisation of the paper The title should be explicit and descriptive of the content; a short running title and an abstract (except for Short Communications) should be included. Check most recent issue for format. It would be helpful if authors could indicate in the margin the relative importance of the headings.

General formatting requirements • Text should be flush left. This applies also for abstracts, headings, keys and reference lists. Headings should be in upper and lower case, and not underlined. • Use only a single space after *all* punctuation marks including full stops. • Insert a space between a numeral and unit of measurement, e.g. 3 km, but no space between initials, e.g. L.A.R. Haegi, or between en dashes and associated numerals, e.g. 5.2–6 mm. • Use double hyphens (- -) to indicate en dashes (–).• Do not use the space-bar to indent or tabulate. •Underline, in preference to italics, and use single quote marks before double. • Species lists should be in one column, flush left.

Abbreviations, units etc. SI units (metre, kilogram etc.) are to be used. Statistics and measurements should always be given as figures, e.g. 10 mm, except where the number begins the sentence. *The Macquarie Dictionary*, latest edition, and the *Style Manual for Authors, Editors and Printers*, 4th edn, AGPS, 1988, should be consulted for spelling, abbreviations and other conventions.

References References in the text should be made by giving the author's name with the year of publication in parentheses. For reference list at end of paper see papers in this issue for style. If several papers by the same author and from the same year are cited, *a*, *b*, *c*, should be put (in italics) after the year of publication. Titles of journals should be given in full or abbreviated in accordance with the latest (4th) edition of the *World List of Scientific Periodicals*.

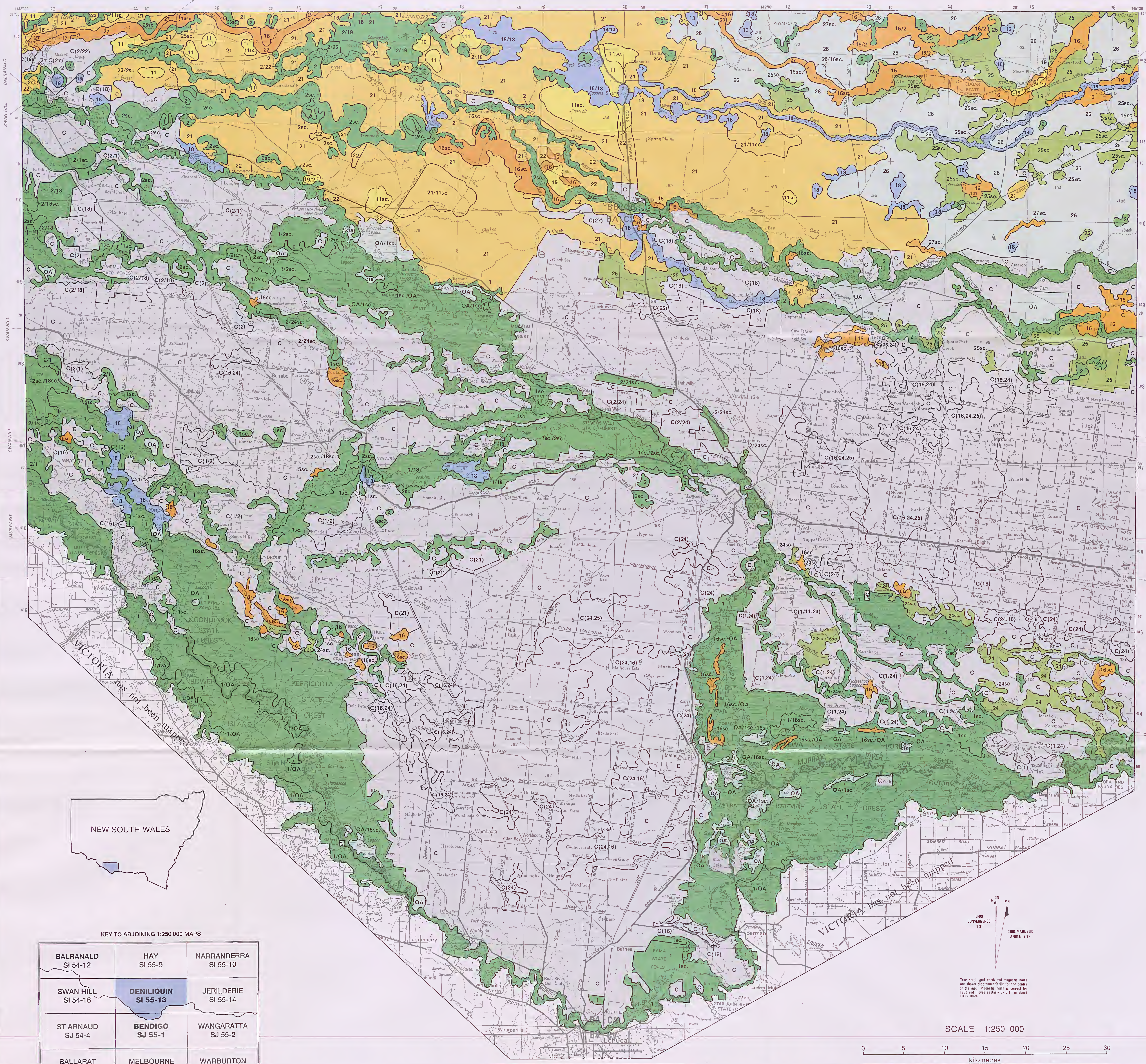
Illustrations/maps/photos • In general figures should be drawn one and a half times the final printed size. Check that line thickness and evenness, and labelling size are suitable for the final reproduction size and that maps show their context clearly (by lat./long. or an inset map) and that relevant place names in the text (but not for cited specimens) are shown. • Submit line drawings as bromide (Repromaster) copies with the final manuscript. • Photos should be unmounted, good-quality gloss prints, with self-adhesive labels on back indicating number, author and top of photo. • Labelling that is part of an illustration, e.g. place names on a map, should be added by the person preparing the illustration. • Bar scales for maps and photographs are preferred to numerical scales. • Bear in mind the shape of the final printed page and that the maximum final size of the illustration is 205 mm high x 125 mm wide, but preferably less to leave space for a caption on the same page. • Authors wishing to submit large or complex maps should discuss cartography with the editors before final preparation.

Captions Use lower case letters for the parts of a figure e.g. **Figure 1.** The plant communities of Bents Basin showing **a**, Forest Hill Creek section and **b**, Little Mountain section.

Tables should preferably be portrait rather than landscape shape i.e. taller rather than wider. They should be typed as separate files. Column headings should be brief with units of measurement in parentheses. Each table must be referred to in the text and its approximate position should be indicated in the margin of the manuscript. Please remember that tables need to fit into the journal page size.

More detailed instructions are available on request from the editors.

DENILIQUIN-BENDIGO 1:250 000 VEGETATION SERIES



SCALE 1:250 000

0 5 10 15 20 25 30
kilometres

HEIGHTS IN METRES CONTOUR INTERVAL 50 METRES

KEY TO ADJOINING 1:250 000 MAPS

BALRANALD SI 54-12	HAY SI 55-9	NARRANDERRA SI 55-10
SWAN HILL SI 54-16	**DENILIQUIN** **SI 55-13**	JERILDERIE SI 55-14
ST ARNAUD SJ 54-4	**BENDIGO** **SJ 55-1**	WANGARATTA SJ 55-2
BALLARAT SJ 54-8	MELBOURNE SJ 55-5	WARBURTON SJ 55-6

Natural Vegetation of the DENILIQUIN-BENDIGO (New South Wales) 1:250 000 Map Sheet

Marianne F. Porteners

Descriptions of the plant communities are given in *Cunninghamia* 3(1) 1993

Compiled and prepared at the
National Herbarium of New South Wales

ROYAL BOTANIC GARDENS SYDNEY

Understanding the ecology of our native plants

MAP UNIT DESCRIPTIONS

No.	Plant Community	Main Species	Structure	Habitat
1	**Riverine Forest**	*Eucalyptus camaldulensis*	open forest	Adjacent to rivers on levees and flats of grey clay soil.
2	**Black Box Woodland**	*Eucalyptus largiflorens*	woodland - open woodland	On river floodplains, low-lying areas and creek lines on grey clay soils.
24	**Grey Box Woodland**	*Eucalyptus microcarpa, Allocasuarina luehmannii*	woodland - open woodland	Elevated flats and rises of the Murray River floodplain on red-brown earths and clay.
25	***Acacia pendula* Woodland**	*Acacia pendula*	woodland - open woodland	Level to depressed plains in the east on grey and brown clays and red earths.
16	***Callitris* Mixed Woodland**	*Callitris glaucophylla, Callitris gracilis* subsp. *murrayensis* (south of Deniliquin)	woodland - isolated clumps	Sandy rises of old source-bordering dunes on red and brown sands and loams.
17	***Acacia melvillei* Woodland**	*Acacia melvillei*	woodland - shrubland	Undulating plains and low rises on red-brown clay to sandy loam.
27	**Prior Stream Remnant Woodland**	*Callitris glaucophylla, Hakea leucoptera, Hakea tephrosperma*	open woodland - isolated trees	Sandy ridges of old prior stream beds in the south-east on gravelly to sandy soils.
19	**Old Man Saltbush**	*Atriplex nummularia*	chenopod shrubland - open chenopod shrubland	Level to depressed plains on grey or brown clays and often in low-lying situations with community 2.
11	**Bladder Saltbush**	*Atriplex vesicaria*	chenopod shrubland - open chenopod shrubland	Level to depressed alluvial plains on deep grey, cracking clays to red clay-loam.
12	***Sclerostegia tenuis***	*Sclerostegia tenuis* *Disphyma crassifolium* subsp. *clavellatum*	closed - open chenopod shrubland	Saline flats and depressions in the west on clay soils.
21	**Cottonbush**	*Maireana aphylla*	chenopod shrubland - sparse chenopod shrubland	Depressed alluvial plains in the south-west on grey clay soils.
22	**Dillon Bush**	*Nitraria billardierei*	shrubland - sparse shrubland	Disturbed situations on plains, floodplains and dry lakebeds. Often associated with 2, 18 and 21.
26	**White-top Grassland**	*Danthonia caespitosa*	grassland open grassland	Level alluvial plains in the east on grey to brown clay soils.
OA	**Open Areas**	various grasses, herbs and forbs	grassland - forbland	Highly disturbed areas usually on heavy soils.
13	**Canegrass**	*Eragrostis australasica*	tussock grassland	Depressions and low-lying areas on heavy grey clays.
18	**Lignum and *Chenopodium nitrariaceum***	*Muehlenbeckia florulenta, Chenopodium nitrariaceum*	closed - open shrubland	Infrequently flooded channels, depressions and river flats on heavy grey cracking clays.
C	**Cleared and/or Cropped**	Native vegetation has largely been removed for agricultural or urban development but remnant vegetation of varying sizes and condition may remain. Where possible pre-cleared vegetation and remnants are indicated in brackets following C.		
sc.	**scattered**	plants are scattered		

Present vegetation as at January 1993. Clearing marked from LANDSAT TM imagery dated 01-01-1993 to 10-01-1993.

Topographic base from Deniliquin SI 55-13 and Bendigo SJ 55-1 1:250 000 map sheets are Crown Copyright and have been reproduced with the permission of the General Manager, Australian Survey and Land Information Group, Department of Administrative Services, Canberra, ACT.

This project was jointly funded by the Natural Resources Management Strategy of the Murray-Darling Basin Commission, and the Royal Botanic Gardens, Sydney.

PLANT COMMUNITIES OF THE DENILIQUIN-BENDIGO 1:250 000 MAP SHEET

Community 1 Riverine Forest

Structure: open forest # and ##

Main species:
Eucalyptus camaldulensis (River Red Gum)

Associated species:
Acacia stenophylla, Muehlenbeckia florulenta, Eucalyptus largiflorens, Eucalyptus microcarpa, Chenopodium nitrariaceum, Juncus ingens, Exocarpos strictus, Acacia salicina, *_Lycium ferocissimum_.

Ground-cover species:
Pratia concolor, Glinus lotoides, Oxalis perennans, Centipeda cunninghamii, Paspalidium jubiflorum, Alternanthera denticulata, Chamaecyce drummondii, Cotula australis, Marsilea drummondii, Carex appressa, Poa fordeana, Agrostis avenacea, *_Cotula bipinnata,_ *_Stellaria media,_ *_Solanum nigrum,_ *_Sonchus oleraceus_.

Landform: River and creek levees and adjacent flats, channelled plains and other areas subject to frequent or periodic flooding.

Soils: Heavy grey, brown and red clays.

Occurrence: This community occurs along the major river systems of the Murray and Edward-Wakool Rivers and other rivers and creeks throughout the mapped area. _Eucalyptus camaldulensis_ will occur with Black Box wherever periodic flooding occurs. Dense stands of _Eucalyptus camaldulensis_ occur along the Murray and on its adjacent floodplain, particularly in the Barmah and Millewa State Forests, which are internationally recognised wetland habitats (Finlayson & Moser 1991). Rare hybrids of _Eucalyptus camaldulensis_ and _E. largiflorens_ occur between Barham and Swan Hill. _Eucalyptus microcarpa_ (Grey Box) forms extensive stands within _Eucalyptus camaldulensis_ forests in the Deniliquin area. In Werai State Forest north-west of Deniliquin, _Eucalyptus microcarpa_ reaches open forest proportions. Within the Murray floodplain, higher areas of red-brown earths or sands occur, carrying much-cleared woodlands of _Callitris gracilis_ subsp. _murrayensis_ (Murray Cypress Pine) or _C. glaucophylla_ (White Cypress Pine) (See Community 16). A small population of _Eucalyptus leucoxylon_ subsp. _pruinosa_ (unmapped) exists just north of Barham, adjacent to _Eucalyptus camaldulensis_ and _E. largiflorens_ woodland and growing on grey-brown alluvial soil.

A shrub layer is normally absent in this community, with leaf and branch litter dominating the ground layer. Shrubs, if present, may include _Muehlenbeckia florulenta_ (Lignum), _Chenopodium nitrariaceum_ and *_Lycium ferocissimum_. _Muehlenbeckia florulenta_ and _Eragrostis australasica_ may occur in intermittently flooded channels within the floodplain while areas of semi-permanent still water support rushlands of _Typha_ spp., _Phragmites australis, Juncus_ spp. and _Eleocharis_ spp. The herbaceous layer varies seasonally and, as well as the species listed, may include _Rumex,_ *_Medicago, Echium_ and *_Xanthium_ spp. together with exotic grasses such as *_Hordeum leporinum_ and *_Lolium perenne_.

Community 2 Black Box Woodland

Structure: woodland #; woodland - open woodland ##

Main species:
Eucalyptus largiflorens (Black Box)

Associated species:
Chenopodium nitrariaceum, Rhagodia spinescens, Atriplex nummularia, Enchylaena tomentosa, Einadia nutans, Muehlenbeckia florulenta.

Ground-cover species:
Chamaesyce drummondii, Atriplex semibaccata, Atriplex leptocarpa, Oxalis perennans, Boerhavia coccinea, Centipeda cunninghamii, Alternanthera denticulata, *_Verbena officinalis, Calotis scapigera_.

Landform: Uppermost floodplain levels, periodically flooded alluvial plains, ephemeral creeks and adjacent flats, dry-lake margins, depressions, drains and channels.

Soils: Heavy grey and brown clays, self-mulching or compact.

Occurrence: Black Box forms extensive woodlands on the terrace landform elements adjacent to major creeks and rivers across the mapped area. It is also common in depressions, along major and minor creeks and fringing dry lakes. South of Moulamein and Conargo on the Deniliquin map, _Eucalyptus largiflorens_ often occurs mixed with _Eucalyptus microcarpa_ (Grey Box) and less commonly _Eucalyptus melliodora_ (Yellow Box), gradually being replaced by the former further south on the floodplain. _Eucalyptus largiflorens_ grows on the less frequently flooded areas of the floodplain above the level of the adjacent River Red Gum forest. It also occurs in ribbon stands along intermittent creeks, fringing lakes, or as a line of very scattered individual trees along drainage lines. _Eucalyptus largiflorens_ often occurs in depressions and other areas of restricted drainage within other vegetation communities such as _Callitris glaucophylla, Acacia pendula_ and mallee woodlands.

The main understorey species in Black Box woodlands are _Chenopodium nitrariaceum, Rhagodia spinescens_ and _Enchylaena tomentosa. Chenopodium nitrariaceum_ often extends out beyond the Black Box floodplain to form extensive shrublands, although much has been cleared for irrigated cropping. _Atriplex nummularia_ occasionally forms a tall understorey to _Eucalyptus largiflorens_. Where the community occurs in wetter, periodically flooded areas, _Muehlenbeckia florulenta_ may be the major understorey component.

Community 11 Bladder Saltbush

Structure: low shrubland - low open shrubland #; chenopod shrubland - open chenopod shrubland ##

Main species:
Atriplex vesicaria (Bladder Saltbush).

Associated species:
Sclerostegia tenuis, Malacocera tricornis, Disphyma crassifolium subsp. _clavellatum, Minuria cunninghamii, Maireana aphylla, Sclerolaena tricuspis, Sclerolaena muricata, Ixiolaena tomentosa, Eragrostis australasica, Sclerolaena brachyptera, Sclerolaena bicornis_ var. _bicornis, Sclerolaena intricata, Leptorhynchos panaetioides, Calocephalus sonderi, Frankenia connata, Maireana decalvans, Dissocarpus biflorus_ var. _biflorus_.

Other common associate species which vary seasonally include:
Atriplex lindleyi, Atriplex pseudocampanulata, Rhodanthe corymbiflora, Plantago cunninghamii, Podolepis muelleri, Daucus glochidiatus, Sida trichopoda, Maireana pentagona, Sclerolaena stelligera, Brachycome lineariloba, Vittadinia cuneata var. cuneata, Chloris truncata, Sporobolus caroli, Agrostis avenacea.

Landform: Level to depressed alluvial plains.

Soils: Deep, grey, self-mulching and cracking clays to red clay-loam. Grey clays, clay-loams to sandy loams overlying clay (Knowles & Condon 1951). May also occur in sandy deposits.

Occurrence: _Atriplex vesicaria_ forms the dominant vegetation community over the mapped area. It is believed to have once covered vast areas of the Hay Plain but that excessive grazing has led to its rapid decline (Beadle 1948, Knowles & Condon 1951). Several dieback events over the past decade have seen a further decline in extent of the species. Post-dieback distribution of _Atriplex vesicaria_ has been mapped. Only small remnant patches exist on the Deniliquin-Bendigo map, these being mainly north of Billabong Creek. Some saltbush occurs in north-western Victoria as discrete areas along the Murray River (Dalton 1988). The largest continuous stands occur north of Hay and west to north-west of Booligal, on the Booligal-Hay map area. A close associate of _Atriplex vesicaria_ is _Sclerostegia tenuis_, which replaces the former in depressed, saline situations (see Community 12). Large patches of _Eragrostis australasica_ often occur in depressions within both these shrubland communities. _Atriplex vesicaria_ often occurs mixed with _Atriplex nummularia_ on flat to low-lying sites.

Community 12 _Sclerostegia tenuis_

Structure: low shrubland #; closed - open chenopod shrubland ##

Main species:
Sclerostegia tenuis (Slender Glasswort), _Disphyma crassifolium_ subsp. _clavellatum_ (Round-leaf Pigface).

Associated species:
Atriplex vesicaria, Eragrostis australasica, Sclerolaena tricuspis, Malacocera tricornis, annual _Atriplex_ spp., _Sclerolaena muricata, Sclerolaena brachyptera, Osteocarpum acropterum_ var. _deminuta, Minuria cunninghamii_.

Landform: Saline flats and depressions, depressed alluvial plains.

Soils: Clay soils in saline situations.

Occurrence: On depressed saline flats mostly adjacent to irrigated areas. This community is closely allied to _Atriplex vesicaria_ shrubland into which it generally grades, further north on the Booligal-Hay map area. _Sclerostegia tenuis_ becomes the dominant species in more saline situations and the community is particularly well-developed on the lower alluvium around Lake Victoria and other dry lakes and saltpans further west (Fox 1991). It is considered a highly salt-tolerant species, being capable of colonising highly saline environments where no other species will grow (Beadle 1948). _Sclerostegia tenuis_ often forms dense mats below Black Box woodland and has decreased significantly in abundance due to grazing and trampling by stock (Cunningham _et al._ 1981).

Community 13 Canegrass

Structure: tussock grassland # and ##

Main species:
Eragrostis australasica (Canegrass)

Associated species:
Eleocharis pallens, Juncus flavidus, Juncus aridicola, Muehlenbeckia florulenta, Disphyma crassifolium subsp. _clavellatum, Chenopodium nitrariaceum_.

Landform: Alluvial plains with depressions and other low-lying areas subject to intermittent flooding or ponding such as swamps, tabledrains and claypans.

Soils: Slightly saline, compact, heavy grey clays.

Occurrence: _Eragrostis australasica_ has a very patchy distribution in the north of the Deniliquin-Bendigo map area and within the irrigated country adjacent to the Murray and Edward-Wakool Rivers. It is particularly common in saline depressions within _Atriplex vesicaria_ shrubland further north on the Booligal-Hay map area. It occurs in tabledrains and depressions along the major roads in low-lying and irrigated sites. _Eragrostis australasica_ tolerates regular, but not prolonged flooding, with _Muehlenbeckia florulenta_ (Lignum) occupying the wetter areas (Semple 1990). _Chenopodium nitrariaceum_ and _Atriplex nummularia_ may be present around the edges of Canegrass swamps.

Community 16 _Callitris_ Mixed Woodland

Structure: woodland - low open woodland #; woodland - isolated clumps ##

Main species:
Callitris glaucophylla (White Cypress Pine). _Callitris gracilis_ subsp. _murrayensis_ (Murray Cypress Pine) may replace _Callitris glaucophylla_ on sandhills and ridges adjacent to the Murray River.

Associated species:
Hakea leucoptera, Hakea tephrosperma, Alectryon oleifolius subsp. _canescens,_ occasional _Alectryon oleifolius_ subsp. _elongatus, Acacia melvillei, Geijera parviflora, Allocasuarina luehmannii, Maireana pyramidata, Acacia oswaldii, Acacia homalophylla, Pittosporum phylliraeoides, Casuarina pauper, Eremophila longifolia, Dodonaea viscosa_ subsp. _angustissima, Senna artemisioides_ subsp. _petiolaris, Acacia brachybotrya, Eucalyptus melliodora_.

Landform: Raised sandy areas such as low linear dunes, sandhills, ridges and footslopes of rocky outcrops. Old stream beds and levee banks of prior streams and source-bordering dunes formed with the redeposition of prior stream material by wind action (Butler _et al._ 1973). The remnant woodland occupying the major prior streams has been mapped as a separate map unit (see Community 27).

Soils: Coarse-textured red and brown earths such as sandy-loams and loams.

Occurrence: Isolated sandhills with _Callitris_ Mixed Woodland occur throughout the mapped area. Source-bordering dunes associated with prior streams and generally running in an east-west direction occur from west of Booroorban on the Booligal-Hay map area, to just north of Moulamein. Continuous, elevated sandridges also occur north of Conargo and Wanganella. Large areas of _Callitris glaucophylla_ occur in Steam Plains, Puckawidgee, Edgar and Tholobin State Forests and on the properties 'Steam Plains' and 'Zara'. Unusual areas of _Callitris glaucophylla_ with an _Atriplex nummularia_ understorey occur on 'Steam Plains' and 'Zara'. Undulating country with remnant _Callitris glaucophylla_ is also seen south-west to south-east of Deniliquin in primarily agricultural land, often associated with remnant Grey Box and Bulloak woodland (Community 25). _Eucalyptus melliodora_ (Yellow Box), is associated with _Callitris glaucophylla_ on shallow to deep sandy soils in this area, with Cypress Pine dominating on the sandhills (Moore 1953). _Callitris gracilis_ subsp. _murrayensis_ may replace _Callitris glaucophylla_ on the sandhills and elevated plains adjacent to the Murray River and hybrids of these two species may occur.

In this community, trees may be widely scattered or may form more or less monospecific groves. _Callitris glaucophylla_ in particular tends to occur in large stands with other species scattered or in groves in between. Grove-forming species include _Alectryon oleifolius, Acacia melvillei_ and _Acacia homalophylla_. An understorey is rare, but where present may include _Rhagodia spinescens_ and _Maireana pyramidata_. Much of the original understorey has been grazed out but it is thought that common understorey shrubs may have included species of _Dodonaea, Pimelea, Rhagodia, Exocarpos_ and _Senna_ (Noble & Mulham 1980). Generally the ground cover consists of short-lived perennial and annual grasses and herbs, many of them introduced species. The sandy soils are highly prone to wind erosion and degradation by rabbits. Occasionally _Callitris glaucophylla_ may be absent from this community, with the associated trees mentioned above dominating. Some species such as _Dodonaea viscosa_ subsp. _angustissima, Eremophila longifolia_ and _Senna_ species can form a dense, low, monospecific scrub within this community.

Community 17 _Acacia melvillei_ Woodland

Structure: tall shrubland - low woodland #; shrubland to woodland ##

Main species:
Acacia melvillei

Associated species:
Callitris glaucophylla, Acacia homalophylla, Acacia oswaldii, Alectryon oleifolius subsp. _canescens, Casuarina pauper_.

Landform: Level sandplains, undulating plains and low sandy rises.

Soils: Red-brown clay to sandy loam.

Occurrence: A small area of _Acacia melvillei_ occurs north of Moulamein. The community is more common further north on the Booligal-Hay map area. _Acacia melvillei_ forms local communities within _Callitris_ Mixed Woodlands (Community 16) of sandy rises and source-bordering dunes, and within the Belah-Rosewood country to the north-west of the mapped area. This community is generally small in extent or forms localised stands within other communities.

Community 18 Lignum and _Chenopodium nitrariaceum_

Structure: low shrubland - open scrub #; open - closed shrubland ##

Main species:
Muehlenbeckia florulenta (Lignum), _Chenopodium nitrariaceum_ (Nitre Goosefoot).

Associated Species:
Eragrostis australasica, Sclerolaena muricata, Juncus flavidus, Juncus radula and other _Juncus_ spp., _Senecio cunninghamii_ var. _cunninghamii, Rumex tenax,_ *_Rumex crispus, Atriplex suberecta_. Species occurring in wetter areas include _Eleocharis acuta,_ *_Alopecurus geniculatus, Marsilea drummondii_ and _Limosella australis_.

Landform: Intermittently flooded channels, depressions, river-flats and swamps. Flooding is relatively infrequent, but often prolonged.

Soils: Heavy grey cracking clays.

Occurrence: This community occurs throughout the mapped region, in remnant patches or bands adjacent to major creeks and rivers, and in other low-lying swampy areas. _Chenopodium nitrariaceum_ exceeds Lignum as the dominant species in this community in occasionally inundated areas with less restricted drainage. It is usually seen forming an understorey to _Eucalyptus largiflorens_ and often extends out onto the floodplain beyond the woodland zone to form dense shrublands. It is also common in dry lakes and infrequently flooded depressions. _Muehlenbeckia florulenta_ withstands relatively infrequent but more prolonged flooding and may form a dense, almost impenetrable scrub (Semple 1990). It favours channelled plains and depressions with impeded drainage but nearly always occurs with _Chenopodium nitrariaceum_.

Community 19 Old Man Saltbush

Structure: low - low open shrubland #; chenopod shrubland - open chenopod shrubland ##

Main species:
Atriplex nummularia (Old Man Saltbush)

Associated Species:
Rhagodia spinescens, Atriplex vesicaria, Enchylaena tomentosa, Einadia nutans, Eucalyptus largiflorens, Sclerostegia tenuis, other _Atriplex_ spp.

Landform: Level to depressed plains, low-lying areas and depressions.

Soils: Grey, self-mulching, cracking clays to red duplex soils with grey and brown clays. _Atriplex nummularia_ grows on a wide range of soil types and at all levels of the plain (Cunningham _et al._ 1981).

Occurrence: This community occurs throughout the Hay Plain with a patchy distribution. Remnant areas occur between Moulamein and Wanganella, forming an understorey to _Eucalyptus largiflorens_, with a particularly dense stand seen on 'Bundy'. _Atriplex nummularia_ was once a dominant understorey species to _Acacia pendula_ (Beadle 1948, Moore 1953) but this association no longer exists within the mapped area. The mapped areas of Old Man Saltbush are remnants of once-extensive stands that have been subjected to grazing pressure, rabbit-disturbance and clearing. Many small remnants occur around homesteads and in small holding paddocks that saw little grazing. The larger remnant areas are delineated on the maps but many smaller patches exist, often consisting of only scattered individuals.

Community 21 Cotton Bush

Structure: low - low open shrubland #; chenopod shrubland - sparse chenopod shrubland ##

Main species:
Maireana aphylla (Cotton Bush)

Associated Species:
Atriplex vesicaria, Sclerolaena muricata, Sclerolaena tricuspis, Nitraria billardierei, Minuria cunninghamii, Ixiolaena tomentosa, Osteocarpum acropterum var. _deminuta, Leptorhynchos panaetioides, Atriplex lindleyi, Atriplex pseudocampanulata, Malacocera tricornis, Danthonia caespitosa, Calocephalus sonderi, Sclerolaena bicornis_ var. _bicornis, Daucus glochidiatus,_ *_Cotula bipinnata, Rhodanthe corymbiflora, Rhodanthe pygmaea, Plantago cunninghamii, Podolepis muelleri, Calotis scabiosifoia_ subsp. _scabiosifolia, Brachycome lineariloba_.

Landform: Depressed alluvial plains, usually disturbed.

Soils: Grey to grey-brown clays to clay-loams (Leigh & Mulham 1965).

Occurrence: This community is widespread over the Hay Plain and has proliferated in many areas once dominated by _Atriplex vesicaria_. It occurs north of the Edward-Wakool River system within the Deniliquin-Bendigo map area. The largest continuous stands occur further north on the Hay Plain. _Maireana aphylla_ originally occurred with _Atriplex vesicaria_ in slightly depressed areas mainly in the east Darling area and excessive grazing has led to its increase with the elimination of _Atriplex vesicaria_ over large areas (Beadle 1948). Shrublands dominated by _Nitraria billardierei, Sclerolaena muricata_ and _Sclerolaena tricuspis_ indicate greater disturbance. The herbaceous layer within this community consists of short-lived perennial and annual grasses and herbs, many of them introduced, such as *_Avena fatua,_ *_Hordeum leporinum,_ *_Lolium perenne,_ *_Phalaris paradoxa,_ *_Phalaris minor,_ *_Bromus madritensis,_ *_Medicago_ spp. and *_Erodium_ spp. _Maireana aphylla_ and _Nitraria billardierei_ tend to occur on slightly depressed areas of the Plain as they are more flood-tolerant than _Atriplex vesicaria_ (Beadle 1948). _Maireana aphylla_ is often associated with medium to heavy scalding and occasional individuals or patches of remnant _Atriplex vesicaria_ may be seen. Shrub cover can vary considerably in this community, ranging from dense monospecific stands to scattered individuals within a matrix comprising annual and short-lived perennial grasses.

Community 22 Dillon Bush

Structure: low - low open shrubland #; shrubland - sparse shrubland ##

Main species:
Nitraria billardierei (Dillon Bush)

Associated Species:
Maireana aphylla, Sclerolaena muricata, Sclerolaena tricuspis. This community occupies disturbed areas and usually comprises a high proportion of introduced and annual species. Other associated species vary depending on the composition of the original vegetation.

Landform: Disturbed low-lying alluvial plains, dry lakebeds.

Soils: Grey to grey-brown clay and loam soils, often saline (Cunningham _et al._ 1981).

Occurrence: _Nitraria billardierei_ tends to occur in dense continuous stands in areas of high grazing pressure, particularly adjacent to riverine and box woodlands, and in previously cropped areas. Its distribution has increased markedly with the changed land use in the area since European settlement. Severe overgrazing of the original chenopod species has resulted in the establishment of Dillon Bush in areas once occupied by _Atriplex vesicaria_ and _Atriplex nummularia_ (Noble & Whalley 1978). Dillon Bush commonly occurs in lower densities within other shrubland and woodland communities.

Community 24 Grey Box Woodland

Structure: low woodland - woodland #; open woodland - woodland ## (_Eucalyptus microcarpa_ occasionally reaches open forest proportions # and ##)

Main species:
Eucalyptus microcarpa (Grey Box)

Associated Species:
Allocasuarina luehmannii (Bulloak), _Eucalyptus melliodora_ (Yellow Box), _Acacia hakeoides, Acacia brachybotrya, Acacia acinacea, Callitris glaucophylla, Senna artemisioides_ subsp. _zygophylla, Senna artemisioides_ subsp. _filifolia_ and _Senna artemisioides_ nothosubsp. _coriacea, Acacia rigens_.

Landform: Level to undulating plains, elevated flats and rises adjacent to the Murray and Edward-Wakool river systems.

Soils: Red-brown earths and heavy clay to loamy alluvial soils (Cunningham _et al._ 1981). Deeper sandy soils to the south-east of Deniliquin (Moore 1953).

Occurrence: _Eucalyptus microcarpa_ woodland occurs in the far south of the Hay Plain. It is seen from east to south-west of Deniliquin, extending down to the Murray River and has its northern limit on the Plain within the Edward-Wakool river system, where it forms open forest within River Red Gum communities. _Eucalyptus microcarpa_ gradually replaces _Eucalyptus largiflorens_ south of Deniliquin where it occurs on higher loam soils in association with _Allocasuarina luehmannii_ (Bulloak) and _Eucalyptus melliodora_ (Yellow Box). _Eucalyptus microcarpa_ has been extensively cleared and thinned for both grazing and cropping. Around Deniliquin, this species and _Allocasuarina luehmannii_ have been reduced to remnant patches of scattered trees within irrigated agricultural land. Very few areas exist with an intact shrubby understorey, most of these being roadside remnants. Small remnant stands with _Acacia_ and _Senna_ understoreys exist around Mathoura, north-east of Deniliquin, and along Lower Thule Road east of Barham. Taller _Eucalyptus microcarpa_ forest occurs with _Eucalyptus melliodora_ on the heavy clays within riparian forests. _Allocasuarina luehmannii_ and _Callitris glaucophylla_ are common associates, occurring on higher ground above the level of the _Eucalyptus microcarpa. Eucalyptus melliodora_ is less abundant in this undulating country, observed more often with Grey Box in riparian situations.

Community 25 _Acacia pendula_ Woodland

Structure: low - low open woodland #; open woodland - woodland ##

Main species:
Acacia pendula (Myall or Boree)

Associated Species:
Rhagodia spinescens, Atriplex nummularia (largely cleared), _Danthonia caespitosa, Maireana aphylla,_ annual _Atriplex_ spp., annual and short-lived perennial grasses, *_Medicago_ spp., _Enchylaena tomentosa, Atriplex semibaccata, Maireana decalvans, Stipa nodosa. Amyema quandang_ subsp. _quandang_ commonly occurs as a parasite on _Acacia pendula_.

Other common associate species which may vary seasonally or with grazing pressure include _Alternanthera denticulata, Centipeda cunninghamii, Sida_ spp., _Rhodanthe corymbiflora, Maireana pentagona, Sclerolaena stelligera, Erodium_ spp., _Myriocephalus rhizocephalus_ subsp. _rhizocephalus,_ *_Cotula bipinnata, Vittadinia cuneata_ var. _cuneata, Lepidium pseudohyssopifolium, Enteropogon acicularis, Ranunculus_ spp.

Landform: Level to depressed plains. Adjacent to streams or in depressions in grasslands (Beadle 1981).

Soils: Grey and brown clays and more rarely on red-brown earths (Beadle 1981, Semple 1990).

Occurrence: _Acacia pendula_ occurs mainly in the east of the Hay Plain and is seen here at the western limit of its range. It occurs east to north-east of Conargo within the Deniliquin-Bendigo map area, continuing along the eastern edge of the Booligal-Hay map area to Hillston. Isolated groves and scattered trees occur within _Danthonia caespitosa_ grassland (Community 26) and _Eucalyptus largiflorens_ woodland (Community 2). Widespread clearing of _Acacia pendula_ for cropping, fodder and timber has resulted in a patchy remnant distribution. It commonly occurs with a very open structure and a herbaceous understorey, mostly comprising *_Medicago_ spp. and grasses such as _Danthonia caespitosa, Enteropogon acicularis,_ *_Lolium perenne,_ *_Hordeum leporinum,_ *_Vulpia myuros_ and *_Bromus madritensis_. A shrubby understorey is rare or lacking. The original _Atriplex nummularia_ understorey has been largely cleared. Moore (1953) noted remnants as existing in the Jerilderie area. _Atriplex vesicaria_ and _Maireana aphylla_ are also listed as original understorey components with the latter persisting over the two species (Beadle 1981). There are few tree associates but where present may include _Acacia salicina_ and _Acacia oswaldii_ (Beadle 1981).

Community 26 White-top Grassland

Structure: tussock grassland - open tussock grassland #; grassland - open grassland ##

Main species:
Danthonia caespitosa (White-top or Ringed Wallaby Grass) predominantly, but there is usually a _Danthonia eriantha_ component of about 10 per cent.

Associated Species:
Chloris truncata (Windmill Grass), _Enteropogon acicularis, Sporobolus caroli, Bromus arenarius, Stipa nodosa,_ *_Hordeum leporinum,_ *_Lolium perenne,_ *_Lolium rigidum,_ *_Avena fatua,_ *_Bromus madritensis,_ *_Vulpia myuros,_ *_Medicago_ spp., *_Erodium_ spp., _Rhodanthe corymbiflora, Sida trichopoda, Sida corrugata, Maireana aphylla_ (occasionally).

Landform: Level alluvial plains.

Soils: Grey to brown clays or clay-loams, usually with a compacted surface (Beadle 1948).

Occurrence: This grassland is composed of short-lived perennial and annual grasses and occurs in the east to south-east of the Hay Plain, extending from north-east of Deniliquin to south of Gunbar on the Booligal-Hay map area. The most homogeneous areas are found south-east to north-east of Hay. _Danthonia caespitosa_ may dominate the ground layer in _Eucalyptus largiflorens, Acacia pendula_ and other woodland communities. Short-lived perennial and annual grasses dominate the pasture in more disturbed communities with a seasonal composition. Common species include *_Hordeum leporinum,_ *_Lolium perenne,_ *_Avena fatua_ and *_Bromus madritensis_. At various times of the year *_Medicago_ spp., *_Erodium_ spp. and other herbs (commonly Asteraceae) are a significant component of the ground layer.

Community 27 Prior Stream Remnant Woodland

Structure: low open woodland #; open woodland - isolated trees ##

Main species:
Callitris glaucophylla (White Cypress Pine), _Hakea leucoptera_ (Needlewood), _Hakea tephrosperma_ (Hooked Needlewood).

Associated Species:
Pittosporum phylliraeoides, Alectryon oleifolius subsp. _canescens,_ occasional _Alectryon oleifolius_ subsp. _elongatus, Rhagodia spinescens, Stipa scabra_ subsp. _scabra, Aristida behriana, Enneapogon nigricans,_ *_Cucumis myriocarpus, Wahlenbergia stricta_ subsp. _stricta_.

Landform: Raised beds of prior streams indicated by low, winding sandy ridges on the clay floodplain (Butler _et al._ 1973).

Soils: Gravel, sand and sandy-loam overlying clay (Butler 1950).

Occurrence: Several prior streams occur north of Conargo on the Deniliquin-Bendigo map. This vegetation community is of a very remnant nature, often reduced to just several scattered trees or a small grove. Prior streams are not always obvious on the ground and are usually visible as a line of scattered trees on a low narrow rise with adjacent scalding. Isolated groves of _Hakea_ spp. or _Pittosporum phylliraeoides_ may also indicate the existence of a prior stream. As well as _Callitris glaucophylla, Hakea_ spp. and _Alectryon oleifolius_, prior streams once supported stands of _Acacia homalophylla, Casuarina pauper_ and _Geijera parviflora_ (Semple 1987_a_). Prior streams have been mapped to include the elevated stream bed and associated scalded levees. The dunes range in height from 3 to 15 metres (Semple & Eldridge 1989).

Open Areas (OA)

These are highly disturbed areas with a vegetation cover of annual or short-lived perennial grasses, herbs, forbs and few shrubs. Open Areas result from intense grazing, clearing and fire. Introduced pasture species usually predominate such as *_Hordeum leporinum,_ *_Lolium perenne,_ *_Avena fatua_ and *_Medicago_ spp. The composition of annual species changes seasonally but may also include _Erodium_ spp., asteraceaeous herbs such as _Rhodanthe corymbiflora,_ *_Cotula bipinnata_ and _Podolepis muelleri,_ annual saltbushes and _Swainsona_ species. Weeds may also dominate the more disturbed Open Areas such as road verges and heavily used paddocks. Infestations of *_Echium plantagineum_ (Patterson's Curse), *_Arctotheca calendula_ (Capeweed) and *_Brassica_ spp. are particularly common on the Hay Plain.

Vegetation Structure: # = Specht (1981); ## = Walker and Hopkins (1990)
* placed before a species name indicates an exotic species

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